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Overview of Hybrid Electric Vehicles

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***Abstract*: -- The demand for non-renewable energy sources constantly increases due to the increase in the combustion vehicles. The combustion vehicles pollute the environment resulting in the ecological disturbance. In order to reduce carbon dioxide emission in the atmosphere which is mainly due to the combustion vehicles and from the factories. It is important to use the hybrid electric vehicle as it is environmentally friendly and thus uses a battery which can be recharged either through the plugin or also even by regenerative braking. It also works on fuel and thus by the use of rechargeable batteries the fuel consumption is low thus helps in the preserving the non-renewable resources to some extent. This paper demonstrates the overview of hybrid electric vehicle, its classification and design.**

***Index Terms* — ECMS (Equivalent Fuel Consumption Minimization Strategy), ESS (Energy Storage System), HEV (Hybrid Electric Vehicle), ICE (Internal Combustion Engine), PMS (Power Management Strategy), PHEV (Plug-in Hybrid Electric Vehicle), SOC (State of Charge).**

I. INTRODUCTION

With the increasing concentration of emission in the atmosphere, it increases the concern about greenhouse effects and the transportation sector is major responsible for this constituting 30% of carbon dioxide emission unlike the other factors, it is mainly due to the expansion of global vehicle fleet. These vehicles, due to their big masses and powertrains show very high fuel consumption as well as pollutant emission. Nowadays one of the best solutions to these problems seems to be the use of hybrid or electric vehicles. Electrical energy being pollution free in the environment, it is better to use electrical vehicles in place of combustion vehicles. Electrical vehicles do not generate pollutants at a local level and relay mostly on renewable sources. Due to the limitations related to pure electric architectures in specific operating condition a lot of attention has been dedicated to the development of hybrid technologies combining the characteristics of two power sources i.e. ICE (internal combustion engine) and generator. The motion of vehicle is based on the interaction between the wheel and asphalt. The wheel is driven by motor exerting a force on the ground. The vehicle moves due to the Newton's third law of motion. However these vehicles are still not be able to achieve same performance than ICE vehicles in terms of working hours since most modern energy storage systems (ESSs) based on the lithium ion chemistries have not energy density compared with petrol [1]-[3]. The combinations of these two power sources allow having better performance in terms of both the efficiency and power delivery.

II. HYBRID ELECTRIC VEHICLE

A hybrid electric vehicle (HEV) is a type of hybrid vehicle and electric vehicle that combines a conventional internal combustion engine (ICE) system with an electric propulsion system (hybrid vehicle drivetrain). Hybrid electric vehicles combines the benefits of gasoline engines and electric motors to obtain certain objectives such as fuel economy, increased power, or additional electric power for electronic devices and power tools [4]. The main advantage of using a hybrid electric vehicle is the additional degree of freedom that can be obtained due to the presence of an additional energy reservoir- the electric battery- besides the fuel tank [5]. It means that at each instant the power needed by the vehicle can be provided by either one of these resources, or by a combination of the two. There is a variety of HEV types, and the degree to which each functions as an electric vehicle (EV) also varies. The most common form of HEV is the form of hybrid electric car, although hybrid electric trucks (pickups and tractors) and buses also exist.

Some of the main advantages of hybrid electric vehicles are:

1. Environmentally friendly
2. Less dependence on fossil fuels
3. Regenerative braking system
4. Built from light material
5. Higher resale value

III. CLASSIFICATION OF HEV

Hybrid electric vehicle are classified depending on the way the power supplied to the drivetrain and can be classified into three main types as series, parallel and series parallel hybrid electric vehicle. The mechanical structure of both the series and parallel hybrid electric vehicle are primitive and comparatively simple. Powertrain brings more freedom to vehicle engine operation but adds to complexity.

A. Series Hybrid Configuration

This is the basic type of configuration. In this type, ICE is used to drive an electric generator instead of driving the wheels. The power so produced either goes to the motor or to ESS [6]. Some of the most notables are Volvo ECC and BMW

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3 Series. The series hybrid electrical vehicle configuration have high efficiency at its engine operation however in series configuration the weight and the size of the vehicle is increased due to large size of engine of two electric machines needed. Also the configuration of FCHEV (Fuel cell hybrid electric vehicle) is technically in series.

Some vehicle design has separate electric motors. Motor integration into the wheels has disadvantages that the unspring mass increases, decreasing ride performance. Although the advantage of using individual wheel motors are simplified traction control, all wheel drives, and allowing lower floors which is useful for buses [8].

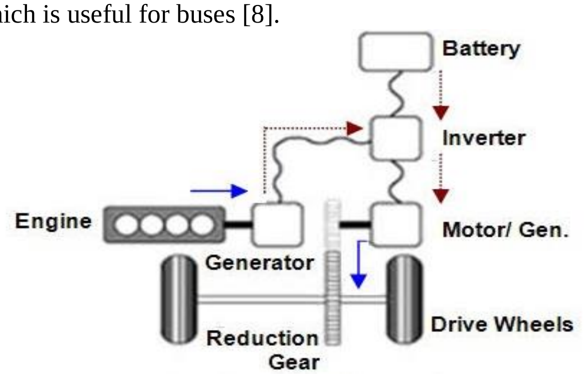

Fig.1 Series configuration

Advantages

1. Mechanical decoupling of engine from drive wheels allows operation anywhere on its speed curve
2. Simple control system
3. Motors spin to very high rpm resulting less gears in transmission unit, and is also cheaper and lighter

Disadvantages

1. Due to twice conversion of ICE energy resulting in significant losses.
2. Generator is required and its associated cost and weight.

B. Parallel Hybrid Configuration

The configuration having both the internal combustion engine (ICE) and an electric motor in parallel connected to a mechanical transmission [8]. As both the engine and electric motor are connected to the drive shaft through a mechanical coupling, they can propel the vehicle by the engine alone, by the motor alone, or by both together.

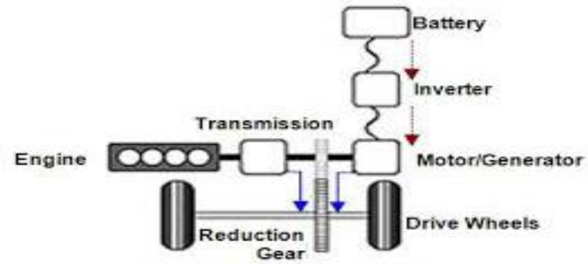

Fig 2. Parallel configuration

The battery in this type can be recharged during regenerative braking, and during cruising, however the battery can't be recharged when the car isn't moving because of fixed mechanical link between wheel and motor.

Advantages

1. Speed and torque can be chosen independently of two power plants.
2. The power plant can be smaller, and therefore cheaper and more efficient.

Disadvantage

1. It is quite complex than series especially in control.

C. Combined Hybrid Configuration

Combined hybrid system have configuration of both the series and parallel hybrids. There is a double connection between the engine and the drive axle: mechanical and electrical. At low speeds, it operates as an electrical vehicle with battery supplying the drive power. At higher speeds, the engine and the battery work together to meet the drive power demand and sharing and distribution between these two sources are key determinants of fuel efficiency [8].

Advantages

1. Flexibility is maximum in order to switch between electric and ICE power.
2. Having electromechanical path allows efficient operation of ICE in unsteady driving.

Disadvantage

1. Very complicated and is expensive than parallel hybrids.

Parameters	Series	Parallel
Engine	Smaller	Larger
Electric motor & battery	Larger	Smaller
Generator	Separate generator	Electric motor acts as generator
Gasoline engine	Not coupled to wheels	Coupled

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Efficiency	More efficient at highway driving at higher, more constant speed	More efficient for driving in the city

Table I. Differences Between Series and Parallel HEV

IV. PERFORMANCE OF HEV UNDER VARIOUS TEMPERATURE CONDITIONS

In HEV battery plays an important role and its performance is analyzed by different parameters like OCV, resistance and SOC. All these parameters are influenced by temperature aging and charging and discharging cycles. There are various methods estimation of SOC but the most prominent are voltage and current based SOC. In advanced vehicle simulator (ADVISOR), current based estimation method is used as default [9]. However many researchers attempted to calculate exact value of SOC of battery [10]. However the OCV based SOC estimation technique is advantageous in aspects like OCV versus SOC characteristics is independent of age of battery [11] and is also very accurate and requires some rest time [12]. The other method for estimation of SOC is the ampere hour counting method as it is easy direct and easily implementable. However for the reliability the current measurement should be accurate however this method may have initial value or accumulated error problems [13]. In order to overcome these shortcomings and to realize the advantages these methods are combined together.

Thus the effect of temperature is analysed I Nn order to achieve the fuel efficient vehicle and longer battery life. At lower temperature fuel economics are lesser and at higher temperature these are high compared to the room temperature's values.

V. COMPONENT SIZING OF HEV

Design of a fully functioning HEV is a very complex task for scientists and engineers due to high number of variables and mathematical complexity of computations. The addition of one power (auxiliary) source is used in HEV to reduce fuel consumption and exhaust emissions of ICE, this incurs additional complexity. Furthermore, adding a secondary power source brings out latent objectives such as enhancing and acceleration performance at the level of converted vehicles level [14]. The optimum substation design of HEV configuration can also be achieved by backward simulation [15]. Backward simulation forms an effective tool to optimize EV/HEV design performance. By knowing the speed profile and vehicle dynamics, the power requirement of propulsion motor and various energy sources can be estimated. In ADVISOR [16] the subsystem component needs to be specified and the design scope is limited.

VI. POWER MANAGEMENT STRATEGY

An adaptive power management strategy (PMS) based on equivalent fuel consumption minimization strategy (ECMS) and a four mode HEV. The four modes consist of an ICE and two motors provides the four mode of operation including electrical vehicle (EV) mode, Range extended (RE) mode, hybrid mode, and engine mode [17]. The adaptive PMS is designed for charge sustaining such that the state of charge can be maintained at a certain value.

The power management strategy can be classified into three types. The first type is the rule based control [18] which is a commonly designed based on rules extracted from engineer's expertise. The second type is the ECMS which employs static optimization to obtain the local minimization of a cost function [19]. The third type is the global minimization over a time horizon based on dynamic programming [20] which can offer the performance upper bound for benchmarking other control strategies. Sun et.al [21] proposed an adaptive ECMS with a velocity predictor to provide temporary driving information for a real time adaptation of the equivalence factor (EF). Model predictive control can be employed to design PMS [22]. Borhan et al. [23] formulated a non-linear and constrained optimal control problem for the PMS design. MPC is then utilized to obtain the power split between ICE and electric motor.

An instantaneous cost function of the fuel consumption of ICE and equivalent fuel consumption of the battery is minimized to obtain the optimum power distributions of ICE, ISG and TM [17].

VII. HERMAL DESIGN OF HEV

Thermal design for a dual sided cooled power semiconductor module for hybrid and electric vehicles: HEV/EV is driven partly or fully by electric power train system that converts DC into AC current, which controls the power conversion from battery to motor by power semiconductor devices [24]. The power devices employed are silicon based insulated gate bipolar transistor and freewheeling diode at the moment [25-27]. For increasing power reliability and prolonged lifetime IGBT and FWD are packaged to power module with multiple devices, isolation layer and protection parts [28-30]. Although big opportunity the power semiconductor is facing challenges of supplying high power performance, reliability, low volume/weight and cost effective automotive modules [31]. IGBT module is the most vulnerable part in HEV power

system because of its intrinsic properties and assembly topology, the harsh working environment, as well as the frequent high load and forced short circuit conditions. This led to the extensive investigation on new material structure and topology [25-32, 35] in which the Direct Liquid Cooled (DLC) and Dual Sided Cooled (DSC) are most promising candidate for automotive application due to the advantages in electrical, thermal, mechanical, performance and reliability.
A DLC module can reduce the thermal resistance of junction to heat sink by about half as compared to the conventional indirect cooled module, as eliminating the thermal interface material and heat sink. The disadvantage of DLC lie in the manufacture difficult of integrated pin fins and the module integration with cooler as well as high electrical parasites, DSC module is believed to have superior electrical and thermal performance and advantages in volume, weight and cost.

VIII. BRAKING OF HEV

The powertrain of hybrid electric vehicle is incredibly complex. The brake energy recycling is a typical characteristics of HEV, which can affect the security saving and energy saving of the whole vehicle. Depending on the operating conditions, the electrical brake of a series-parallel HEV can be divided into regenerative brake and electric consuming brake. In the regenerative brake process, the electricity generated from the brake process is used to charge the battery. The regenerative brake is affected by many factors such as maximum allowable working current of motor in generating mode, the maximum charging current and the voltage of the battery. The brake priority is defined in three stages, the first brake stage is regenerative brake stage. The second one is the regenerative brake combined with electric consuming brake. The third one is the electrical mechanical combined brake [35]. In the brake process, when the voltage and SOC of the battery reach to their maximum limitations, the vehicle works in its electric consuming brake mode. In this situation integrated brake system opens the switch to active brake resistor. Brake resistor gets charged and its temperature rises. And the electric consuming brake cooling system comes into play as temperature increases. Before this the bus voltage should be checked. Signal is sent to the integrated controller of the vehicle through the voltage transducer. It continuously measures the accumulated value with the compared value and when accumulative value exceeds the set value the brake resistor is active. And hence braking is done.

IX. CONCLUSION

The hybrid electric vehicle is very much important considering the amount of carbon dioxide emissions by the combustion vehicles. The hybrid electric vehicle being eco-friendly also contains two power sources either any one of them or both can be used simultaneously. In HEV, battery cam also be charged by regenerative braking. Taking considerations of fuels which are limited resources, the HEV could be best choice as it contains battery, however with the use of rechargeable battery the fuel is less used as compared to the combustion vehicles.

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