

Analysis and Status of Hybrid Electric Vehicle

Thejasiwini R¹, Dr. S Pradeepa², Dr H B Phani Raju³Assistant Professor, Department of Electrical & Electronics Engineering, SIET, Tumkur, Karnataka, India¹Associate Professor, Department of Electrical & Electronics Engineering, BMSCE, Bangalore, Karnataka, India²Vice Principal & HOD, Department of Electrical & Electronics Engineering, SIET, Tumkur, Karnataka, India³

ABSTRACT: Hybrid Electric Vehicles ('HEVs') are the main areas for research and development due to protocols fact on energy resources utilities, global warming and fuel economy. In this study, fundamentals, history, energy management, storage and classification of HEVs are review. Ultra-capacitor and batteries are the major source of energy storage that used in the HEV and; the power supply designing with an appropriate weight, cost, life, cycle and size are the major challenges. However, the Plug-in HEVs have potential to introduce as the most significant solution to overcome the challenges involved in HEVs. The comparison between different electric vehicle, HEV and the plug-in hybrid is discussed. The significance of PHEV is that it having dual characteristics of conventional HEV and the ICE; moreover, PHEVs is a kind of hybrid electric vehicle, which contains the rechargeable batteries that helps to restore the full charge in batteries through connecting a plug-in device to an external source of electric power. Also this paper survey the different state-of-art techniques involved in Electric Vehicles and some top rated HEVs with their specifications are discussed.

KEYWORDS: Electric Vehicles (EVs); Hybrid Electric Vehicles (HEVs); Internal Combustion Vehicle (ICV); Plug-in HEVs.

I. INTRODUCTION

The environmental protection and the conservation of energy are the major growing concerns all over the world; in that if all motor vehicle are motorized by the internal 'combustion engine', the diesel oil and the gasoline will be quickly depleted and that emanation will effect in 'greenhouse effect'. Although the growing environmental apprehensions and the two oil crises at 1970's; the researches attention was drawn at electric vehicle (EV), they were built many prototypes in the year of 1980s. The Hybrid-EV (HEV) concept attains lot of interest at the era of 1990s, when many people were thinking that the EVs would never succeed the objective of 'energy is saving'. Afterwards, the Ford Motor Cop. were taken initiative at challenge of HEV, which drew lots of efforts from the well-known universities in order to develop the hybrid models of production automobiles.

The EV is type of road vehicle that includes the electric propulsion [1], which can be categorised into three different types; Pure-EV, Fuel-Cell-EV and HEV. In present days, there are different development stages because of existing technologies, in that the oriented field control and variable voltage frequency are widely adapted, which is communal technique used in EV. The initial cost of battery and the management of battery create difficulty in Pure-EVs in focus of 'zero-emission'; these problems related to battery cannot be resolve in upcoming years, therefore, the temporary solution of the Pure-EVs is HEVs till the Pure-EVs becomes full commercialize. The long-term possibility of Fuel-Cell-EV is high for the futuristic vehicles [2], but the development technologies of its refueling and cost system is in initial development stage [1], therefore at present scenario HEV seems to be better choice.

A vehicle that stores the energy in two 'or' more than two forms are called as a Hybrid Vehicle. In a general HEV there are two forms to acquire energy; one form is bidirectional 'electrical storage' system and other form is electric engine, which is having energy source of oil or gas. In HEV, there are many different methods that will help to reduce the consumption of fuel such as; engine downsizing, energy recovery during brake, shutting down the engine when its not in use and by efficiently operating the engine [3].

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Table 1: Comparison between EV, ICV and HEV [4]

Vehicle Type	EV (Electric Vehicle)	ICV (Internal Combustion Vehicle)	HEV (Hybrid Electric Vehicle)	
Propulsion	Motors	Engine	Engine + Motors	
Source of Energy	Batteries	Oil/Gas	Oil/ Gas	Batteries /Super Capacitor /Fuel Cells
Significance	Zero Emission	Less refuelling time, Less capital cost	High fuel Economy	

Here, table 1 represents the brief comparison of EV, ICV and HEV, where EVs is the most cleanest transportation that have zero emission of carbon and also called as zero emission vehicle. Whereas, emission from HEVs are considerably less compared to ICV, the important advantage of HEVs over the ICVs is that it include improved efficiency, better mileage and very less dependency on oil/gas and small amount carbon footprint, due to complete or partial traction generated by 'electric motors'. However, in order to provide better driving experiences and emission reduction, more charging time, high capital cost and smaller range of driving are several factors, which produce difficulty to capture the greater market of HEVs.

II. LITERATURE SURVEY

There are different type of electrical components are present in the HEVs such as; power electronic converter, electric motor, sensors, controllers and batteries for hybrid vehicle operation, also they need ICE. The different type of propulsions are involved in a HE vehicle, an electric vehicle is operated in only batteries or ultra-capacitor. The main difficulty arises in the proper selection of range, controlling, optimization performance, and fuel economy of vehicle. In this paper [5], the Human-Machine-Interface ('HMI') is focused and the HMI based methodologies, implementation and practices in present and upcoming commercial trends are stated in [6]. The authenticate HMI methodology are depend upon the multi-model and multi-touch technologies that having gesture recognition, proximity sensor, touch recognition, voice recognition, haptic feedback, handwriting recognition, face/eye recognition, etc. Moreover, the HMI for electric vehicle has been studied in paper [7] in order to provide information and the HMI with a low carbon vehicles has been compared and summarized in paper [8]. As we know that the BAIT vehicle should design to provide easily perceived information and do not cause any confusion problem. In paper [9], they discussed the interface problem, which may create confusion during awareness and recognition of the driver; therefore, it is kind of difficulty, which should be manage in order to help the driver to uphold a suitable awareness beneath assistance.

The plugin charging system of HEV is provided to improve the misalignment tolerance and decreases the core loss is studied in paper [10]; moreover, the usage of orthogonal and parallel windings at receiving set of coil are able to enhance the power-transfer efficiency is studied in paper [11]. Therefore, the multi-coil based system has proposed in order to get high-systemtolerance for data bandwidth and power transfer efficiency. A 4-coil concentric model, which contain 2-receiver and 2-transmitter has been studied in paper [12]. Moreover, the multi-coil has applied in [13] that organize the more coil separately from single-input-single-output system, which can improve the transfer power efficiency, whenever the angle and distance between the receiving and sending coil are maximized. Enhancement in the fuel economy is strongly depends upon the driving cycle of vehicle; therefore the 'energy management' strategies are very important that based upon the mänge in fuel consumption minimization and optimum control theory. However, majority of these management system cannot be implemented directly in real-time [14], where the reason behind these is preceding information of all-driving cycle [14]. Moreover, the vehicle-management unit should administer the function of battery management System to optimize life of batteries and minimize serious damages risk of battery cell. Fundamentally, the vehicle-management unit should predict the state-of-charge, state-of-health and

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state-of-function of battery. In paper [15], they have focused on providing versatile and efficient Petri nets application without the global positioning system (GPS free system) or with the registered GPS system to suitably provide the efficient strategy of energy management for HEV at high serial architecture and high-level hybridization

A significant amount of researches in the field of Control Strategy for energy storage has done; in paper [16], they proposed methodology of Super-capacitor Pack threshold set, which maximize the demand of power by filling Super-capacitor Pack (when its permitted). Moreover, the criteria of state-of-charge of batteries pack or state-of-charge of Super-capacitor Pack is discussed through combining different procedures at load side, these can lead to get much optimize control. In [17] they proposed the fuzzy controller logic that work on Super-capacitor state-of-charge and battery state-of-charge; and another designing methodology is proposed in [18] through a load levelling. Through using this type of optimized methodology, the individual component of hybridized system can be enhanced.

III. ENERGY MANAGEMENT AND STORAGE OF HEV

Ultra-capacitor and batteries are the major source of energy storage that used in the HEV. The most commonly used energy storage is batteries to get the higher energy density and the lesser cost. The necessary designing parameter for HEV is peak power, whereas the stored energy amount is the major important parameter at an 'electric vehicle'. The power supply designing with an appropriate weight, cost, life, cycle and size are the major challenges.

A. Batteries

The important factors that has to be consider in order to select batteries are the high power output (i.e., structural and thermal), larger energy capacity and the influence of electromagnetic on the battery with in the cells because it dissipates heat while the charging and the discharging time. Therefore, it requires the cooling system (it may be liquid or air). The Lithium-ion (L-ion) batteries are the most commonly used batteries in HEVs, due to their higher range of energy (i.e., energy/unit mass) as compared to the other system of energy storage. However, they having advantages of low self-discharge, high energy efficiency, high ratio of 'power to weight' and considerably well at high-temperature performance.

B. Ultra Capacitor

The characteristics of ultra-capacitor is more specific power, but their having very less 'specific energy' as compared to the batteries. The additional amount of power can be provide through the ultra-capacitor during the acceleration. However, the effect of load levelling at ultra-capacitor can minimalize the high-level discharge current producing from batteries, which also help to decrease the high-charging current occur during a regenerative braking in battery.

C. Battery management scheme

The battery management scheme is the main element present in overall architecture of HEV, it is kind of controller founded model that helps to protect from damage. The lifetime of batteries and the vehicle range in the completely drive mode can be substantially extended through an enhanced implementation of battery management scheme. There are several battery sub-model system are acknowledged and positioned in several places of the electric vehicle. Therefore, all the models needs of cell-balancing features and higher supervision battery system. These kind of sub-model can be connect by the buses in order to ensure the system deliveries as per the energy requirement of the application. The temperature control management plays an important role in HEV, which provide safety insurance and also it increasing the 'system lifetime'.

D. Hybrid control system

The hybrid control system in the HEV are apply to meet vehicle power requirement; therefore, each of the vehicle component should provide optimal efficiency. Energy recovering by the regenerative braking is very necessary to counter and the maintenance of battery state during charging and discharging. A novel intelligent energy management approach selects the suitable process mode that are based upon the tractive effort. The vehicle-management unit should administer the function of battery management System to optimize life of batteries and

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minimize serious damages risk of battery cell. Fundamentally, the vehicle-management unit should predict the state-of-charge, state-of-health and state-of function of battery.

IV. PRESENT STATUS OF HEV

Most of the locomotive producer have developed several HEVs such as Automobiles and light weight tucks, Trucks, High performance Buses, Motorcycles, Military vehicles and etc. In according to the electric motor functionality (mode of operation) and electric power level, the HEVs can be classified in different types; full hybrid, mild hybrid and micro hybrid. Full hybrid is a kind of strong hybrid, these vehicle can run on a batteries, an engine 'or' a combination of engine and batteries. The example of full hybrid cars are Ford Fusion hybrid, are Ford Escape hybrid, The Toyota Prius and Ford's Hybrid system, these car can move by the alone battery power. In mild hybrid system, the vehicle cannot be drive through only its electric motor due to not having much power of electric motor to propel its own vehicle.

There are some feature of mild hybrids in the hybrid technologies, they generally achieve some fuel consumption savings, 8% to 10% in an average and up-to 15% in urban driving areas. A mild hybrid system commonly having a smaller generator/motor (i.e., weaker in strength) and a smaller batteries that allows the manufacturers to decrease the weight and minimize the cost of vehicle. In micro hybrid system, an electric motor having a limited power only so it only use as an alternative starter, and the internal combustion engine (ICE) indemnifies the vehicle propulsion. Here, the electric motor provide advantage to ICE during start-up the vehicle in order to get better operations. Because of the electric motors operation, the 'micro hybrid HE' can performs stop and go task, which allows to stop the ICE whenever the vehicle is at 'standstill-mode' (e.g., during traffic light signal). Moreover, the improvement of fuel economy are estimated as 2% to 10% at urban driving areas.

In accordance to the engine and types of fuel, the HEVs can be further classified as: Gasoline, Fossil Fuels, Biofuels, Hydrogen, Diesel and Plug-in Hybrids (PHEVs) [19]. PHEVs is a kind of hybrid electric vehicle, which contains the rechargeable batteries that helps to restore the full charge in batteries through connecting a plug-in device to an external source of electric power. The significance of PHEV is that it having dual characteristics of conventional HEV (having an `electric motor') and the ICE; moreover, the electric vehicle having plug-in point to maintain connection to electrical grid. Plug-in Hybrids have the larger range of all-electric as compared with the conventional electric-gasoline hybrid model, also it remove the 'anxiety range' that come with all type of electric vehicles, due to ICE works as backup system whenever the batteries are removed from vehicle.

Table 2: Comparison between micro, mild, EVs, full and the plug-in hybrid

Functions	Start / Stop	Regene rate braking	Additional electric power for	Electric power for mild dista	Electric power for long distance &	Energy Savings	Elect ric Power
Micro and Micro-	Yes	Yes (only in micro- mild)	Yes (only in micro- mild)	NA	NA	5-10% (up-to 25% in city traffic)	1.5 to 10KW
Mild Hybrid	Yes	Yes	Yes	NA	NA	10% to 25%	5 to 20KW
Full Hybrid	Yes	Yes	Yes	Yes	NA	25% to 40%	30 to 75KW
EV	Yes	Yes	Yes	Yes	Yes	100 %	30 to 100KW
Plug in hybrid (PHEV)	Yes	Yes	Yes	Yes	Yes	50% to 100 %	70 to 100K W

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Table 3 to 7 represent some of the Hybrid Vehicle with their specifications. The 'Toyota Prius' model is a compact produced by the Toyota company; moreover, the Toyota debuted the 3rd generation of Prius model (in US 2010 year model) and at the Jan-2009 in the North American "International Auto Show" [20].

Table 3: Specifications of Toyota Prius. (XW30) [20]

Car Technology	Toyota Prius (XW30); 3 rd Generation 2010 to 2015
Fuel	1.8L, Gasoline model 14 VVTI; @Torque: 142Nm and at 4000rpm 98hp; 73kW at 5200rpm
Electric	650V Electric Motor (EM); 60kW Torque: 207Nm at 0 rpm
Transmission	CVT
Length (L)xWidth(W)xHeight(H) (TO)	4.460 x 1.745 x 1.490 (m3)
Range	EPA Rated as 21.04kmpl

Table 4: Specifications of Toyota Prius ' Plug in Hybrid ' [21]

Car Technology	Toyota PriusPlug-In-Hybrid'
Fuel	1.8L Gasoline4-cylinder model no. 'DOHC14 VVT-I; CR-13:1; 98hp 73kW at 5200rpm; 4000rpm with Torque: 142Nm
Electric	650V EM; 80hp; 60kW at Torque: 207Nm
Transmission	1-speed planetary gear (SPG)
Length (L)xWidth(W)xHeight(H) (m ³)	4.460 x 1.745 x 1.490(m ³)
Range	Hybrid mode:- 21. 26kmpl EPA rated:- 4 0.38kmpl

The body style as per the year; 4-door sedan model (1997-2003), 5-door lift-back model (2003-2015) and 5-door fastback model (2016-present). During its initial year in global market, the sales has reached to 27,181 Prius-PHVs, which making it a grid top selling 'Plug-in EVs' car in a year of 2012 after the 'Chevrolet Volt' [22]. Moreover, the production of 1st-G Prius Plug-in EV has ended in 2015 June and; as per the data at April 2016, the sales of 1st-G Prius PHV is calculated as 75400 units (i.e., delivered worldwide from the year of 2012). The 42345 units of sales totalled in the United States till September 2016, 221 00 units in Japan and 10600 units in Europe, which makes Prius-PHVs [21] as the 3rd most all time selling PHV in the world.

Table 5: Specifications of Chevrolet Volt [22]

Car Technology	Chevrolet Volt
Fuel	1.4L Gasoline model DOHC14; CR- 10.5:1; 63 kW @ 4800rpm; 84hp; Torque: NA
Electric	Two Electric Motors (EMs) - 111kW (drive motor)and 54kW (generator motor); 149hp @ Torque : 368 Nm
Transmission	CVT
Length (L) x Width(W) x Height(H) (m ³)	4.498 x 1.788 x 1.438(m ³)
Range	Extended Range:-63.27km

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1st Generation Chevrolet Volt model came at 2010 to 2015 and 2nd generation 2015 to present. It is a plug-in Hybrid EV car manufactured (by General Motors) that marketed in china as the *Buick-Velitte 5*.

Table 6: Specifications of Honda Insight (ZE2) [23]

Car Technology	Honda Insight ('ZE2') (2009- 2014) [23]
Fuel	1.3L LDA series model 14 8 valve - SOHC; 98hp; Torque: 167 Nm at1000-1700 rpm; 73 kW at 5800 rpm
Electric	DC 'Brushless Motor'; 144V; 13hp ; Torque: 79Nm at 1 000 rpm; 9.7kW at 1500rpm
Transmission	CVT
Length (L)xWidth(W)x Height(H) (m ³)	4.376 x 1.695 x 1.425(m ³)
Range	EPA rated: -17.54kmpl

The Honda Insight model has ranked as topmost selling car in April 2009 in the Japan that is a first HEV model. Moreover, after its initial one year of first HEV slot, the second slot of Honda Insight sold off 143015 units at worldwide [23]. In the year of 2014, the Honda Company announced the production end of Honda Insight 2015 model with Honda EV car and Honda FCX car. Table 7 shows the Specifications of Electric - *Venturi Automobiles* [24], which having range of 50km at one time charge.

Table 7 Specifications of Electric — *Venturi Automobiles* [24]

Car Technology	<i>Electric- Venturi Automobiles</i>
Fuel	Not applicable
Electric	Electro Motor: 1 6kW @21Bhp Solar Power: 72W Solar roof: 8m ² Torque: 50Nm Wind Power: 300W
Transmission	NA
Length (L)xWidth(W)x Height(H) (m ³)	2.860 x 1.850 x 1.750(m ³)
Range	On Battery: 50km

V. CONCLUSION

The hybrid control system in the HEV are apply to meet vehicle power requirement therefore, each of the vehicle component should provide optimal efficiency. The HEV make use of internal combustion engine, therefore it requires a fuel tank. Moreover, a battery in HEV to stores the energy that provide electric charge to run an electric motor, which converts the electrical form of energy to mechanical energy (that deliver appropriate torque to drive the vehicle wheels). In a series HEV, only the 'electric motor' drives vehicle wheels. While in parallel HEVs, both motor and ICE are used to drive the vehicle wheels. Moreover, in the power-split BEV, an ICE and two 'electric-motors' can drive the wheels independently 'or' jointly. In case of PHEV, it retains the usage of fuel tank and ICE with addition of battery and electric motor. Moreover, the PHEV having plug-in point to maintain connection to electrical grid, which allows Plug-in Hybrids to have the larger range of all-electric as compared with the conventional electric/gasoline hybrid model

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