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In Depth Reviews of Hybrid Electrical Vehicles (HEVs)

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Abstract:

Now a day, the Hybrid Electrical Vehicles (HEVs) gives better solution to overcome the challenges of efficient use of fuel and offer comparatively very low emissions in the field of road transportation sector. Moreover, the Hybrid Electrical Vehicles (HEVs) can be employed in water and air transportation in future. The Hybrid Electrical Vehicles (HEVs) offers combine benefits of internal combustion engines (ICEs) and electric motors. The HEVs not only offer reduced emissions, enhance vehicles to become more fuel efficient but also boost the overall performances. This paper focused on the various vital components of HEVs and their constructional differences. The abstract mostly focused on Series Hybrid Electric Vehicle (SHEV) and parallel Hybrid Electric Vehicle (PHEV) and Series-parallel Hybrid Electric Vehicle (SPHEV) along with their advantages, limitations and applications. Furthermore, this paper highlights importance and role of regenerative braking, power split device and energy management systems. Overall, this paper coves review of Series Hybrid Electric Vehicle (SHEV), parallel Hybrid Electric Vehicle (PHEV) and Series-parallel Hybrid Electric Vehicle (SPHEV) with discussing their contribution in achieving sustainable road transportation in future.

Key Words: Internal Combustion Engine (ICE), Hybrid Electrical Vehicle (HEV), Series Hybrid Electric Vehicle (SHEV), parallel Hybrid Electric Vehicle (PHEV) and Series-parallel Hybrid Electric Vehicle (SPHEV), Hybrid power unit (HPU), Energy Management System (EMS), Battery Electric vehicle (BEV)

1. Introduction

The first gasoline-electric hybrid vehicle was first front wheel drive car built in 1898 by an Austrian-German automotive engineer, Ferdinand Porsche (Volkswagen Beetle, the Mercedes-Benz SS/SSK). After that he developed a hybrid car which used an internal combustion engine to power the electric wheel-hub motor that can travel about 40 miles using battery power alone. [1]

Though the concept of hybrid vehicles was introduced in the late 19th century, the advance manufacturing technology and increase in awareness of emissions lead to the development of practical HEV's. The very first mass-produced hybrid car HEV produced by the Toyota Prius in December 1997 and in 2012 Toyota set milestone in the automotive industry by selling about 1.2 million HEV's in global market. [2]

The HEV's maintain benefits of IC engine and electric motor. The IC engine provides high power during higher demanding conditions, like sudden acceleration demand or vehicle climbing on hilly-road. On other hand the electric motors are efficient in low power demanding conditions, like idling or moving with steady speed. The combination of IC engine and electric motor in HEV gives more efficient fossil fuels and energy.

The Hybrid Electric Vehicles (HEVs) are becomes more popular in last few years, because of their potential to overcomes some of the environmental problems arises due to conventional Internal Combustion Engine (ICE) vehicles. The HEVs uses an internal combustion engine with an electric motor and battery system, which resulting in improved fuel efficiency with reduced emissions.

2. General components of Hybrid Electric Vehicle:

Firstly, all hybrid electric vehicles require a hybrid power unit (HPU), which are employed to produce the main power of the whole hybrid powertrain. Combustion engines are the most common HPUs, such as compression ignition/direct injection engines, spark ignition/direct injection engines, the Stirling engine and gas turbine engines.

A. Hybrid power unit (HPU):

The all HEV's required a Hybrid power unit (HPU) which produces main required power to generate electricity. The Hybrid power unit (HPU) can be compression ignition, direct injection engines, spark ignition engines, Stirling engine and gas turbine engines. [3] the engines typically run on gasoline or diesel fuel. The engine is coupled electricity generator or alternator to generate electricity from mechanical energy. This electricity is either used to run electric motor or it is stored in battery, which is used to power the electric motor directly.

B. Electric Motor unit:

The most important component of any electric vehicle is motor. The electric motor is responsible for converting electrical energy into mechanical energy to propel the vehicle. It takes power from the battery or from direct generator. The motor produce torque required to run the wheels.

The variety of electric motors are used in electric vehicles, the most common types of motor are Permanent Magnet Synchronous Motor (PMSM), Induction Motor (IM), Brushless DC Motor (BLDC), Switched Reluctance Motor (SRM) and Direct Current Motor. [4]

C. Battery Pack Unit:

The battery is energy storing device that consisting of electrochemical cells to convert chemical energy into electrical energy. [5] The battery pack consists of number of batteries connected to each other in parallel and series. A HEV uses battery pack to stores generated electrical energy by regenerative braking and the ICE. The Electric Vehicle mostly uses Lithium Ion (Li-Ion), Molten Salt (Na-NiCl2), Nickel Metal Hydride (Ni-MH) and Lithium Sulphur (Li-S) types of batteries. [6]

D. Regenerative Braking:

In the regenerative braking system, the energy from electric motor feed back to the battery while deaccelerating the vehicle in braking process. In the braking, the inertia force of vehicle is used by motor which works as generator. In this mode, the battery is seen as a load by the machine, thus providing a braking force on the vehicle. [7] Most of the HEV's are often incorporated with regenerative braking, in this condition the motor act as generator and part of inertia is converted in to electricity and it results in the vehicle deceleration or brakes. Ultimately the regenerative braking improves overall efficiency and extends the vehicle's range.

E. Energy Management System (EMS):

The basic function of Energy Management System (EMS) is to control drivetrain by plays very important role in HEV's. It minimizes the fuel consumption by controlling the drivetrain components by supervisory control algorithm.

The EMS controls the power flow between engine, generator, battery pack and electric motor. It selects the most appropriate power source for real-time driving conditions by considering battery charge condition, driver inputs and vehicle speed, it results in improved overall efficiency. The EMS methods can be divided in two classes, firstly, non-causal methods that control the power-split using exact knowledge of the power and velocity trajectories, and secondly, causal, real-time implementable methods, that control the power-split without exact knowledge of these trajectories. In general, the non-causal strategies are used to benchmark and design the real-time implementable strategies. [8]

3. Classification:

Now a days main four types of electric vehicles are available in market as Battery Electric vehicle (BEV), Hybrid Electric Vehicle (HEV, plug-in hybrid electric and Fuel Cell Electric Vehicle (FCEV).

The HEV's can be classified into three major types:
A. Series Hybrid Electric Vehicle (SHEV)
B. Parallel Hybrid Electric Vehicle (PHEV):
C. Combine Hybrid Electric Vehicle [9]

A. Series Hybrid Electric Vehicle (SHEV)

The ICE, electric generator, power converting device, electric motor, battery unit and power transmitting unit are the common component of SHEV, often regenerative brakes are also used in SHEV's. The figure no. 1 shows general construction of SHEV. The ICE is connected to electric generator and not directly coupled with wheels. The electric generator not only powers the electric motor but also charge the battery. The only electric motor drives wheels of vehicles.

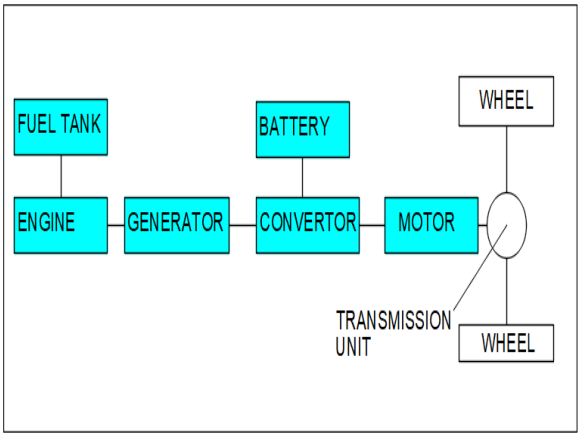

FIGURE NO 01. Series Hybrid Electric Vehicle (SHEV)

The generator generates electric power which is feed to convertor. The convertor gives power to electric motor, the output of electric motor is given to the power transmitting unit which drives the wheels.

In this type the engine gives power to generating source only, so engine can run at constant high speed which gives maximum fuel efficiency. As the electric motor only responsible to drive the wheels, the high torque electric

motors are used to fulfil sudden power requirement of wheels. The high power battery packs are used to meet sudden accelerating demands.

When the power requirement of vehicle is less, than the surplus electricity is used to charge the battery. And when vehicle need more power than electricity generated by generator, the convertor gives more power to motor by combining electricity of generator and battery to meet power demand of vehicle.

The battery pack also recharges by the regenerative braking, while decelerating or braking of vehicle. In regenerative braking system, when the driver applies brakes the electric motor acts like generator which converts kinetic energy of vehicle in to electricity. This electricity used to recharge the battery, which resulting improved energy efficiency and overall range of vehicle is also increases.

The SHEV has some major advantages like no mechanical links required between engine and power transmission unit, ICE can run at constant speed which makes ICE more efficient, the engine and generator can locate at any suitable place in vehicle.

The major drawback of SHEV is the engine generates mechanical power which is converted in electric energy by generator, this electric energy stored in battery and stored electric energy of battery used to run motor which again convert electric energy into mechanical power, so there are more energy losses.

The another drawback of SHEV is required engine and generator along with battery and electric motor which results increase in weight, cost and size.

B. Parallel Hybrid Electric Vehicle (PHEV):

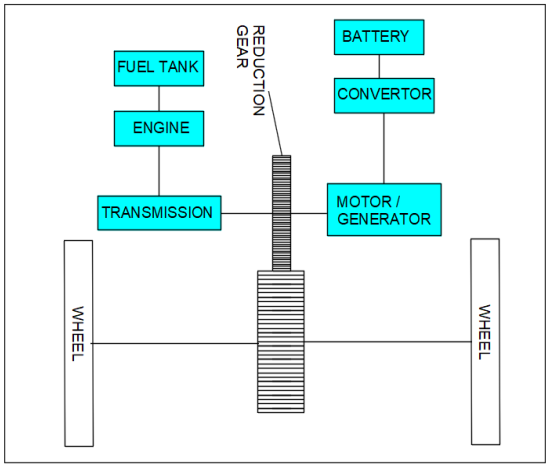

FIGURE NO 02. Parallel Hybrid Electric Vehicle (PHEV)

The PHEV combines ICE and electric motor in such a way that they can power vehicle in together or separately. The ICE directly provide power to wheels through the transmission unit. The electric motor is also coupled to transmission unit; the motor uses electric energy stored in battery through convertor.

When vehicle decelerates or brakes are applied the electric motor act as generator and motor generates the electricity, this electricity used to recharge the battery pack. During sudden acceleration or while hill-climbing the motor provides extra power to transmission unit along with ICE.

The gear units allow vehicle to operate at different speed and torque as per requirement of driving condition. when the vehicle is started, the ICE provide power to transmission unit until the electric motor is ready. During normal running conditions, power control unit uses power from both ICE and motor by maintaining power balance, by considering various factors like speed, load and driver inputs.

During sudden acceleration conditions motor gives extra required power to transmission unit along with ICE. This combination improve performance and minimise the fuel consumption. While braking or deceleration motor acts as generator and convert kinetic energy into electricity to recharge battery.

The controller not only controls flow of electric current between ICE, electric motor and battery pack but also controls switching of power sources. The controller helps to increase performance and overall efficiency of vehicle which results in extended vehicle range.

C. Combine Hybrid Electric Vehicle or Parallel-Series Hybrid Electric Vehicle (PSHEV)

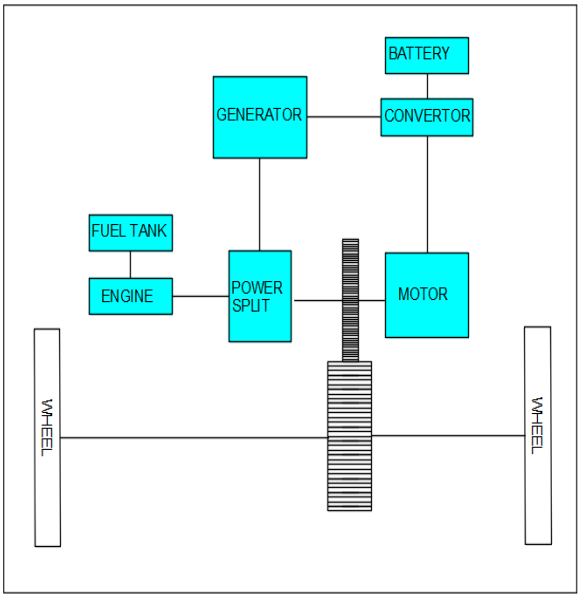

FIGURE NO 03. Combine Hybrid Electric Vehicle or Parallel-Series Hybrid Electric Vehicle (PSHEV)

The Combine Hybrid Electric Vehicle is Parallel-Series Hybrid Electric Vehicle (PSHEV) which gives advantage of

both SHEV and PHEV. In the PSHEV the engine is coupled with special device known as power split device. This device powers wheels through transmission unit and also powers the generator. The generator is coupled with battery and motor through convertor.

The power split device is simply a gearbox that combines ICE and electric motor together. The power split device can power wheels through electric motor and ICE either combine or separately. The planetary gears set are used in power split, it gives advantage like continuously variable transmission (CVT) and it eliminates necessity of manual or automatic transmission. The electric motor is coupled with ring gear, the planetary gears are connected to ICE and ring gear and sun gear connect generator through planetary gears.

When vehicle starts, the electric motor starts ICE through generator and then generator charge the battery at vehicle stationary condition. The power split uses the power from electric motor when vehicle moving at low speed, at moderate speed the it uses power from ICE and when higher power is required it uses power of both IEC and electric motor. [10]

4. Conclusion

The HEV's superiorly overcomes the major drawback of pure battery electric vehicle like short traveling range, long charging time, the HEV's can used continually over long distance traveling and it does not require extra battery charging time. The HEV's also overcomes problems of conventional ICE vehicles like higher fuel consumption, emission and poor overall efficiency of vehicle, the HEV's are using ICE to power vehicle or /and batter, so the power losses are very low and most of the time ICE runs at constant speed irrespective to vehicle speed which makes HEV more fuel efficient, less emitting as well as vehicle with higher overall efficiency. The HEV's gives optimised solution over emission for environmental aspect and also meet need of customer by offering advantages of both BEV and ICE. The HEV's are future for sustainable road transportation solution and with technological advancement they will become more and more popular, economical and environmental friendly.

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