The Electric Vehicle

Swapnil Arun Namekar[1], Prince Kumar[2]
[1]Assistant Professor, Department of Electrical Engineering Bharati Vidyapeeth Deemed University, College of Engineering, Pune, India
[2]Student, Department of Electrical Engineering Bharati Vidyapeeth Deemed University, College of Engineering, Pune, India

***Abstract*- Electric vehicles (EV), as a promising way to reduce the greenhouse effect, have been researched extensively. With improvements in the areas of power electrics, energy storage and support, the plug-in hybrid electric vehicle (PHEV) provides competitive driving range and fuel economy compared to the internal combustion engine vehicle (ICEV). Operating with optimised control strategies or utilising the concept of the energy management system (EMS), the efficiency of the PHEV could be significantly improved. In this review paper, the operating process of the various types of EVs will be explained. Battery technology and super capacitor technology will also be discussed as a possibility to increase the energy capacity of PHEV.**

1.INTRODUCTION

Issues of climate change or global warming have been rigorously discussed by many governments since the early 21st century. A great number of relevant reports have revealed the negative impact of climate changes dominantly driven by human activities. With the globally increasing civilisation and industrialisation, a large number of fossil fuel burnings in industries have led to the acute problem of air pollution. Simultaneously, the exhaust emissions from automotive vehicles cannot be ignored. Vehicle emissions, which mainly include CO_2, CO, NOx and particulate matters, have been considered as the major contributors to the effect of greenhouse gases, also leading to the increase in different forms of cancers and other serious diseases. The ever rapidly growing transportation sector consumes about 49% of oil resources. Following the current trends of oil consumption and crude oil sources, the world's oil resources are predicted to be depleted by 2038. Therefore, replacing the non-renewable energy resources with renewable energy sources and use of suitable Energy-saving technologies seems to be mandatory. Electric Vehicles (EVs) as a potential solution for alleviating the traffic-related environmental problems have been investigated and studied extensively. Compared to ICEV, the attractive features of EVs mainly are the power source and drive system.

Classification of electric vehicle: the power supplement and propulsion devices into account, EV could be classified into three different types: pure electrical vehicle (PEV), hybrid electrical vehicle (HEV) and fuel cell electrical vehicle (FCEV). The PEV is purely fed by electricity from the power storage unit, while the propulsion of PEV is solely provided by an electric motor. The driving system of HEV combines the electric motor and the engine, while the power sources involve both electricity and gasoline or diesel. FCEV is driven by an electric motor and could be directly or indirectly powered using hydrogen, methanol, ethanol or gasoline. In PEV, loosely named as battery electric vehicle (BEV), energy storage capacity fully depends on the battery technology. Zero discharge emission of PEV should be a significant advantage because the electrical energy is solely supplied from the vehicle-mounted battery. On the other hand, the limitations on the present status of the on-board battery technology of PEV make it less attractive than ICEV under the same economic and driving requirements. Batteries with high power densities but low energy densities result in longer charging time – even with fast charging technologies, one hour to several hours for full charging is necessary. Thus, main challenges of the PEV are limited driving range, high initial cost and lack of charging infrastructures. For the practical implementation, the size and location of the battery inside the PEV should also be standardised. FCEVs are attractive because of zero roadside emissions.

Even taking the overall emissions into account, which include the emission from chemical plants and on-road reformers, the FCEV seems still competitive. Fuel cell (FC) is the main power supplier and the critical technology for FCEV is an electrochemical device that produces DC electrical energy through a chemical reaction. There are five main components in FC: anode, an anode layer, electrolyte, cathode and a cathode catalyst layer. With suitable parallel/series connection of FC sources, the required amount of power can be produced to drive the car. In terms of driving range, it is comparable to ICEV, thus resulting in a wide range of application of FCs from small scale plants of the order of 200 W to small power plants of the order of 500 kW. However, the high initial cost and lack of refueling stations are still regarded as significant challenges for the success of FCEV. Also, the supply electricity continuity of FCs is less reliable than conventional battery used in EVs. The crucial advantage of BEV and FCEV is the 'zero emission' and hence reduced air pollution. However, the 'zero emission' of BEV and FCEV is not absolute considering the emissions during the whole processing. However, "what is critical as the main pollution-contributor and how" are the topics that are hardly discussed. For example, the pollution-contributors include chemical contamination when producing the fuel cell and the battery (or the electrochemical plant for FCs), the emissions during the vehicle manufacture, the pollution from scrap battery processing, etc.

2. TECHNOLOGIES OF HYBRID ELECTRIC VEHICLE

2.1: Conventional HEV

2.1.1 Micro and mild HEV

According to the proportion of the output power from the electric motor, HEV could be divided into micro, mild and full HEV modes. Compared with ICEV, the micro-HEV operates the engine start motor with a belt-alternator start generator (BSG). The BSG probably eliminates the idling of the motor and simultaneously reduces the petrol consumption. The micro-HEV cannot be strictly classified as a hybrid electric vehicle because the electric motor does not provide a continuous power. In mild HEV, the traditional start motor (engine) is replaced by integrated starter generator (ISG) that is located between the engine and the transmission. As a result, the size of the engine is reduced since ISG assists the engine to propel the vehicle.

2.1.2 Full and dual-mode HEV

For full HEV, the crucial technology is the electric variable transmission (EVT) which is additionally operated as a power splitter. Power splitting provided by EVT gives access to electric launch which refers to the initial acceleration under electric power only. It maintains almost all of the advantages of different types of conventional HEVs such as idle stop-start, regenerative braking, smaller-size engine and electric launch. Conventional HEV technologies have been researched extensively and have vastly improved. When conventional HEV system developed from micro and mild modes into the full mode, the operating characteristics of the vehicles have changed. The micro and mild conventional HEVs give priority to gasoline/diesel machine while electric generator or battery acts as an auxiliary device. In contrast, the full or dual-mode HEV uses electricity as the main energy to propel the vehicle. Currently, HEV has taken a dominating position. Although conventional HEV can be optimised in dual-mode or full HEV to increase the driving range and fuel economy, the disadvantages of burning gasoline/diesel, heavy battery pack and high initial cost cannot be ignored. Additionally, the complexity of the manufacturing process could be another challenge. Thus, conventional HEV is still inappropriate when taking into consideration issues such as transmission loss, gear noise and lubrication . Nevertheless, it should be pointed that HEV has been considered as 'high initial cost' system by researchers.

2.2 Grid-able HEV (PHEV)

Compared to the fixed amount of electricity from the battery pack in conventional HEV, grid-able HEV can be directly connected to the power grids. Researchers have studied the grid-able HEV, also known as the PHEV, for decades. Generally, the constructive change in PHEV is to replace the fixed battery pack (used in conventional HEV) with rechargeable batteries. This results in recharging the battery from an external power source and simultaneously allowing an increase in the electricity capacity. PHEV can provide a longer pure electric driving range similar to both PEV and ICEV.

Although it is developed from conventional HEV, the operating mode of PHEV substantially differs from conventional HEV. The conventional HEV is gasoline dependent, which means the electricity from the battery and generator assist partly for the engine. On the contrary, electricity from the rechargeable battery will play a leading role in PHEV while the fuel engine is maintained as the auxiliary propulsion unit.

3 PLUG-IN HYBRID ELECTRIC VEHICLE TECHNOLOGIES

3.1 The propulsion motor technology in PHEV

3.1.1 Connecting status of motors in PHEV

There are three types of hybrid systems based on different connections between ICE (engine motor) and electric generator in PHEV – series connection, parallel connection, and series-parallel connection. The series PHEV is directly driven from the power produced by ICE to the electric generator and the battery. The power goes through a control unit, which will drive the electromotor and will convert into kinetic energy. Electric generator. There are two sets of driving systems in parallel connection: traditional ICE system and electric motor system. These two systems could either drive the vehicle independently or propel in cooperation. The advantages of the parallel connection are simple construction and lower initial cost. Honda Accord and Civic adopt the parallel HEV mode. The main feature of a hybrid system with the series-parallel connection is that both ICE and motor drive the system simultaneously. They maintain their own set of mechanically variable-speed institutions separately. The two systems are connected with each other through a gear train or a planetary wheel structure. As a result, PHEV comprehensively regulates the speed relation between the ICE and the electric motor. Compared with the parallel hybrid system, the series-parallel hybrid system is more flexible to adjust the output power from ICE and electromotor according to different working circumstances. Figure 5 shows the mixed transmission of mechanical energy and electric energy in series-parallel PHEV.

3.1.2 Electromotor selection for PHEV

There are two significant factors influencing the selection of the motor for PHEV: driver expectation and vehicle constraints. The driver expectation is defined as driving profile, which represents five characteristics: acceleration, maximum speed, climbing capacity, braking, and the driving range. The vehicle constraints refer to vehicle type, vehicle weight and payload. Several types of electromotor could be employed in PHEV for different performances. In terms of operational simplicity, direct current (DC) series motor is attractive but suffers from poor power to weight ratio. Higher power to weight ratio exhibits in DC brushless motor, which also has a high efficiency of ~95%. For maintenance-free operation, alternate current (AC) induction motors seem to be an appropriate option with low cost and high reliability. The inherent downside of induction related motors, however, is the difficulties in speed control. The high speed operation capability has been demonstrated in switched reluctance motor.

3.2 Range-extended hybrid electric vehicle

One of the controversial issues in the research of PHEV is the range-extended hybrid electric vehicle (REV). In this paper, we define REV as an EV that allocates an extra small-size engine, known as the range-extender, coupled with the electric generator to recharge the battery pack. In terms of grid-ability, REV configures the charging socket that allows charging from external power source. In other words, REV is constructed as a serial mode PHEV. The operating mode in REV is based on PEV with an auxiliary power unit (APU).

4 THE ENERGY MECHANISM IN PLUG-IN HYBRID ELECTRIC VEHICLE

Based on the components used in EV, the internal energy transfer mechanism can be described by three critical units: energy source, electric power (converter/inverter), and energy storage. The energy source is considered as the supplier or an energy transfer mode to support the running of the whole system. The energy storage should be a significant part of storing the excess energy (regenerative braking and recharged electricity) and maintaining the system when confronting a greater energy demand. Various converters channel the bridge between each component from the energy source to storage. In terms of operating regulations, the state of charging (SOC) will be a critical technology for HEV.

4.1 Energy resources model in HEV

4.1.1 Battery model

For HEV, three types of energy sources modes can be used. The lead acid battery, which is widely used in HEV, provides propulsion. Practically, the characteristics of battery strongly impact the SOC, such as battery capacity, temperature, and lifecycle.

4.2 Energy storage technology of super capacitor in PHEV

In terms of energy storage technologies, super capacitor (SC) or ultra-capacitor can be an attractive option to extend the storage capacity. Compared with other storage devices, SC provides higher power densities. SC also exhibits a longer charge/discharge lifecycle (500,000 times), while the lead-acid and lithium-ion batteries have an average lifecycle of 1000 and 2000 times, respectively. The SCs are affected by the operating temperature, the depth of discharge, and the number of discharge times. Research also indicates that SC maintains a high efficiency of around 90%. The properties of minimum heat loss and good reversibility are also considered as advantages of SC. Nevertheless, the downside of SCs is the low energy density. Some industries and institutes have developed many new technologies and materials for SCs to improve their energy densities. Experimental data has shown that the SCs potentially achieve over 400 W-h/kg, comparable to the energy densities of lithium batteries. Furthermore, the high charging rate of SCs can increase the efficiency of regenerative braking.

4.3 Power electronics technology in PHEV

The power electronics refers to converters and inverters – DC/AC converter, AC/DC inverter, AC/AC, and DC/DC converters implemented in different scenarios. To improve the reliability and stability of the internal system in EV and HEV, DC/DC converter should be a significant component. In terms of fuel economy, it is possible to involve a power electronic system. For a PHEV, the characteristics of the power electronic system are crucial for effectiveness, which include various features depending on selections of power semiconductor devices, converters/inverters, controlling strategies, packing methods of individual units, and the integration of the whole system.

4.4 Internal energy management in PHEV

The internal energy management demonstrated for PHEV system is different from the EMS for the whole system that includes the charging processing from a power station or smart grids. The definition of internal energy management for PHEV in this paper is an optimised system to achieve the most effective control on the energy transmission. Firstly, it is necessary to introduce a vital function of SOC. As a critical section in HEV, SOC is a connection between the energy source and the energy storage system. Based on the design of SOC, control strategy is also a significant issue for improving the efficiency of internal energy management in PHEV. For example, the energy source model of a PHEV adopts an FC model – simultaneously the energy storage model uses SC

4.5 Summary analysis on the PHEV

To minimise the pollution problem and to delay the exhaustion of non-renewable energy sources, there is an urgent and immediate need for replacing the ICEVs with EVs. All studies reviewed so far, however, fail to significantly improve the vehicular functions and driving experiences for various types of EVs. A vital issue is the battery technology. If the battery technology could achieve sufficient energy densities and maintain appropriate power densities at the same time, the use of BEV and FCEV will significantly increase. As a result, the conventional HEVs have adopted sophisticated and complex vehicle-mounted systems at the expense of dramatically increasing the initial cost. The PHEV is attractive because of technical breakthroughs in rechargeable battery technology. PHEV improves electricity capacity using plug-in charging to provide continuous power. With the additional use of ICE and the external power supply, the size and weight of the battery could be considerably decreased and also reduce the cost. The problem faced by PHEVs is the optimisation of internal resources. In terms of internal operations, PHEV could achieve the optimal efficiency through establishing or changing a series of operating rules of ICE, electric generator and the battery packs. Another challenge is the EMS for external power sources. The issues of the optimal systems for the networks for charging stations in various circumstances should also be addressed. If it is possible to construct an internal resource optimisation system and the EMS at the same time, the PHEV meets most of the needs for the transport system, even with the restrictions that currently exist in modern battery technologies.

5 CONCLUSIONS

The features for different types of EVs have been reviewed in this paper. The PEV and FCEV exhibit the most potential to reduce the road-side emission. However, the PEVs have been restricted by the bottleneck of current battery technologies, while the use of FCEVs show reduced reliability. For the different levels of the conventional HEVs, the driving expectation seems very close to the ICEVs. However, the limitations on the high initial cost and heavy weight are unacceptable for the mass market. The hybrid electric vehicle incorporates most advanced technologies and significantly contributes to the environmental protection. PHEVs are considered as potential candidates to compete with ICEVs in terms of driver expectation, driving range and fuel economy. Research shows that super capacitor, through its high electricity capacity, seems to be very appropriate for implementation in PHEV. To reduce the overall cost in BEV and PHEV, alternative materials and technologies should be explored and researched. The power electronics technology required for the internal energy transmission should also be researched to improve the overall efficiency.

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