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The Electric Vehicle

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***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 optimized control strategies or utilizing 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.**

***Index Terms*— Super capacitor, Green House gas and Resources**

I. Introduction

The 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 civilization and industrialization, a large number of fossil fuel burnings in industries have led to the acute problem of air pollution (Wee, 2010). Simultaneously, the exhaust emissions from automotive vehicles cannot be ignored. Vehicle emissions, which mainly include CO2, CO, NOx and particulate matters (PM10 and PM2.5), 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 (Fenton and Hodkinson, 2001; Fajri and Asaei, 2008). 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 (Ehsani et al., 2010). 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 (Clement et al., 2009; Hajimiragha et al., 2010; Stephan and Sullivan, 2008). Compared to ICEV, the attractive features of EVs mainly are the power source and drive system. Taking 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) (Chan and Chau, 2001; Chau, 2010, 2014). Table 1 shows a brief classification of different EVs. 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.

II. Technologies of hybrid electric vehicle

A. *Conventional HEV*

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 (Wen and Su, 2016). 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 (Lee et al., 2015). One of the notable examples of mild HEV is Buick Lacrosse, introduced in 2006. The working principle of mild HEV is summarised as follows: when the vehicle starts, electric generator comes alive while the petrol engine is shut down. Subsequently, all the working equipment will rely solely on the electric motor. When the brake pedal is released and the vehicle is accelerated, the petrol engine will start and continuously provides the entire propulsion under fast speeds. These processes result in a significant feature: the engine should be shut down once the vehicle stalls, which is known as an idle stop-start feature. The battery is primarily recharged when the vehicle is either decelerating and/or braking. The design of ISG requires both engine and electric motor to work collaboratively when heavy acceleration is required. Honda CR-Z is one of the most typical representatives for mild HEV.

III. Plug in Hybrid Electric Vehicles Technologies

A. The propulsion motor technology in PHEV

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. Under the series connection, of the battery is to adjust and maintain a balance between the engine and the 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 (Van Mierlo et al., 2004). Honda Accord and Civic adopt the parallel HEV mode (PR, 2015).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 (Lovatt et al., 1998). 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.

IV. 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.

1) Photovoltaic model

The fundamental principle of the solar cell is utilizing the semiconductor solar cell to produce electricity (DC) by absorbing the energy from the solar radiation. A great number of studies have illustrated various significant characteristics of photovoltaic which involve the I-V curve, current/voltage output, impacts of temperature and irradiance, solar harvesting studies, etc. (Kaygusuz, 2009; Hannan et al., 2012). In summary, compared to FC and PV models, the conventional battery model seems to be relatively mature in terms of industrial processing. For the economic practicality, the battery model is also attractive because the high initial cost of FC seems still unacceptable another challenge for FC model could be a lack of refilling facilities or the station to exchange FC tank. For PV model, the solar car park is strongly required, which could probably be the main recharging method. Simultaneously, technologies to improve the PV efficiency are also necessary, such as the maximum power point tracking (MPPT). The investments in PV and FC models might pose a significant difficulty for large-scale implementation (Lund et al., 2015; Ehsani et al., 2010; Fernández et al.

2) Summary analysis on the PHEV

To minimize 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.

V. Conclusion

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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