ELECTRIC VEHICLES

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Keywords Electric and hybrid vehicles, electric propulsion, electric drives

Contents

Summary

In a world where environment protection and energy conservation are growing concerns, the development of electric and hybrid vehicles (EV/HEV) has taken on an accelerated pace. The dream of having commercially viable electric/hybrid vehicles is becoming a reality. EVs and HEVs are gradually available in the market. This chapter reviews the present status of electric and hybrid vehicles worldwide and their state of the art, with emphasis on the engineering philosophy and key technologies. The importance of the integration of technologies of automobile, electric motor drive, electronics, energy storage and controls, and the importance of the integration of society strength from government, industry, research institutions, electric power utilities and transportation authorities are addressed. The challenge of EV commercialization is

discussed.

1. Introduction

Electric vehicle (EV) is a road vehicle which involves with electric propulsion. With this broad definition in mind, electric vehicles may include battery electric vehicles (BEV), hybrid electric vehicle (HEV) and fuel cell electric vehicle (FCEV). Electric vehicle is a multi-disciplinary subject which covers broad and complex aspects. However, it has core technologies, namely chassis and body technology, propulsion technology and energy source technology. The article begins with reviewing the status of BEV and HEV, then focusing on the engineering philosophy of EV development. Subsequent to the illustration of the configurations of both BEV and HEV, it discusses rather detail the major technologies, namely the propulsion technology, energy source technology and infrastructure technology. Finally the commercialization aspects are discussed. The conclusion summarizes the state of the art and the challenges of BEV, HEV and FCEV.

Today BEV, HEV and FCEV are in different stages of development, facing different challenges and require different strategies. In order to assist the readers appreciate the features and issues of these vehicles before reading the whole text, the major characteristics of these three types vehicles are given in Table 1. It can be seen that the critical issue of BEV is the battery. Therefore, BEV is mainly suitable for small EV for short range low speed community transportation, thus requires only smaller battery size. HEV can meet consumers' meet but cost is the major issue. FCEV has long term potential for future main stream vehicles, however the technology is still in early development stage, its cost and refueling system are the major concerns.

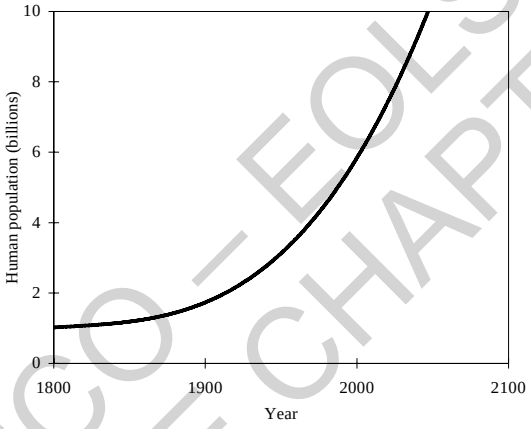
Types of EVs	Battery EVs	Hybrid EVs	Fuel Cell EVs
Propulsion	• Electric motor drives	• Electric motor drives • Internal combustion engines	• Electric motor drives
Energy system	• Battery • Ultracapacitor	• Battery • Ultracapacitor • ICE generating unit	• Fuel cells
Energy source & infrastructure	• Electric grid charging facilities	• Gasoline stations • Electric grid charging facilities (optional)	• Hydrogen • Methanol or gasoline • Ethanol
Characteristics	• Zero emission • Independence on crude oils • 100-200 km short range • High initial cost • Commercially available	• Very low emission • Long driving range • Dependence on crude oils • Complex • Commercially available	• Zero emission or ultra low emission • High energy efficiency • Independence on crude oils • Satisfied driving range • High cost now • Under development
Major issues	• Battery and battery management	• Managing multiple energy sources	• Fuel cell cost • Fuel processor

	• High performance propulsion • Charging facilities	• Dependent on driving cycle • Battery sizing and management	• Fueling system

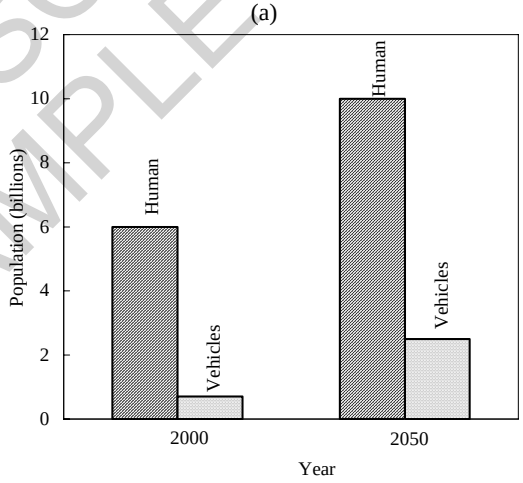
Table 1. Characteristics of BEV, HEV and FCEV.

2. Why Electric Vehicles?

Let us begin with the investigation of the growth of population and vehicles as shown in Figure 1. In the next 50 years, the global population will increase from 6 billions to 10 billions and the number of vehicles will increase from 700 millions to 2.5 billions. If all these vehicles are propelled by internal combustion engines, where will the oil come from? And where should the emissions be disseminated? Would the sky be permanently grey? The gloomy answers to these questions compel people to strive for sustainable road transportation for the 21st century.



(a)



(b)

Figure 1.Growth of population and vehicles.

In a world where environmental protection and energy conservation are growing concerns, the development of electric vehicle (EV) technology has taken on an accelerated pace to fulfill these needs. Concerning the environment, EVs can provide emission-free urban transportation. Even taking into account the emissions from the

power plants needed to fuel the vehicles, the use of EVs can still significantly reduce global air pollution. From the energy aspect, EVs can offer a secure, comprehensive and balanced energy option that is efficient and environmentally friendly, such as the utilization of various kinds of the renewable energies. Furthermore, EVs will have the potential to have a great impact on energy, environment and transportation as well as hi-tech promotion, new industry creation and economic development.

3. Past, Present and Future of EVs

3.1. Past Years Development

EV was invented in 1834. During the last decade of the 19th Century, a number of companies produced EVs in America, Britain, and France. Fig 2 shows the London Electric Cab Company's taxi. Due to the limitations associated with the batteries and the rapid advancement in internal combustion engine (ICE) vehicles, EVs have almost vanished from the scene since 1930.

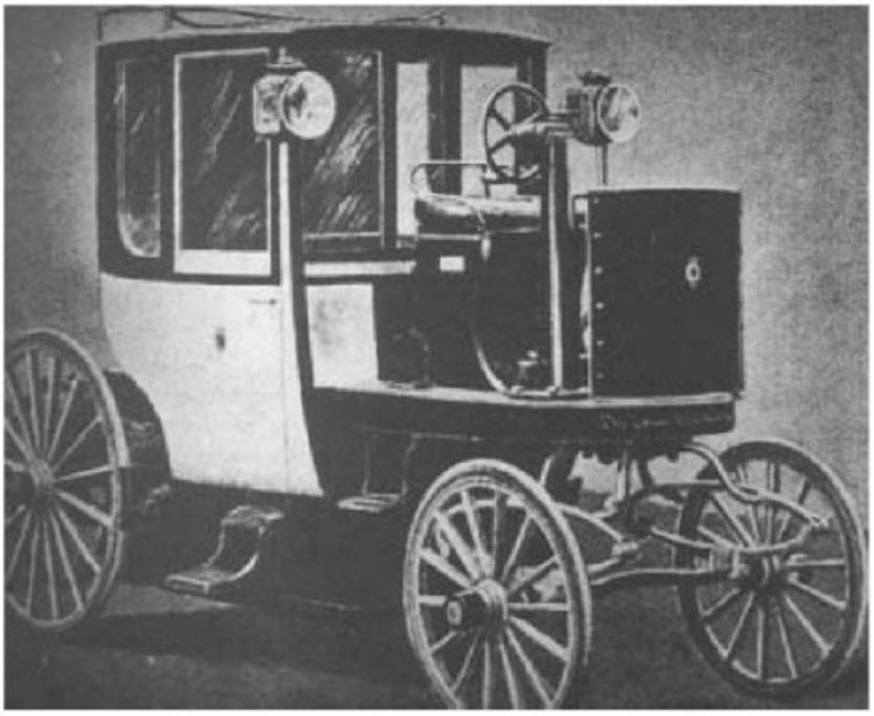


Figure 2. London Electrical Cab Company's taxi.

In the early 1970's, some countries, compelled by the energy crisis, started the rekindling of interests in EVs. In 1976, the USA launched the Electric and Hybrid Vehicle Research, Development and Demonstration Act, Public Law 94-413. At that time, the main question to be answered was "Can EVs do the job in our modern society?", although EVs did work well in the late 1800's and early 1900's. The development of EVs for over years has answered the above question - yes. For example, an experimental EV in 1968 racing from California Institute of Technology (Caltech) to Massachusetts Institute of Technology (MIT) suffered from failures in virtually every critical component; whereas a commercially built EV in 1998 running from Los

Angeles to Detroit exhibited a success with no component failures. Within the 1970's, EVs were still in research and development stage, and most of them were conversion of internal combustion engine vehicles (ICEVs). Today, major automobile manufacturers are offering EVs for sale or lease. Most of them are the purpose-built EV, not conversion EV.

3.2. Present Major Issues

At present, the major driving force for EVs is the environment issue, such as mandate by California rule, rather than the previous energy issue. Thus, the main question to be answered becomes "Can EVs be made affordable?". The major factors that make EV affordable are the range and cost. To tackle the range, the development of advanced batteries such as the nickel-metal hydride, zinc/air and lithium-ion are in progress. However, since both specific energy and energy density of batteries are much lower than that of gasoline, the development of fuel cells for EVs has taken on an accelerated pace in recent years. Meanwhile, the development of commercial hybrid electric vehicles (HEVs) is also going on rapidly. HEVs essentially improve the range and performance of EVs at higher complexity and cost because of the additional energy source, engine and other accessories. To tackle the cost, efforts are being made to improve various EV subsystems, such as electric motors, power converters, electronic controllers, energy management units, battery chargers, batteries and other EV auxiliaries, as well as EV system level integration and optimization.

3.3 Development Trends

In order to see the development trends of various EV aspects, a survey has been made with respect to the number of papers published on various topics in leading EV related international conferences from 1984 to 2000. With regard to propulsion system, it was observed that the research papers on induction motor drives (IM) and permanent magnet motor drives (PM) are highly dominant, whereas those on DC motor drives (DC) are drooping while those on switched reluctance motor drives (SR) are still in a crawling stage. With regard to the development trend of various energy sources, including lead-acid batteries (LA), nickel-based batteries (NB), lithium-based batteries (LB), fuel cells (FC) and capacitors/flywheels (CF); the number of papers published in LB, FC and CF are becoming more and more attractive, though LA and NB are still undergone continual improvement. With regard to the configurations of EVs, it was observed that the conversion EV is becoming less attractive than the purpose-built EV while the HEV is of growing interests for the coming EV markets. It was also observed that EVs are on the verge of commercialization, since more and more papers were published on the topics of demonstration as well as standardization and marketing of EVs.

In the next few decades, it is anticipated that both EVs and HEVs will be commercialized, and they will have their market shares. EVs will be well accepted by some niche markets, namely the users for community transportation, the places where electricity is cheap and ease of access, and the places with zero-emission mandate. On the other hand, HEVs will have a niche market for those users desiring long driving ranges. The ultimate penetration of EVs and HEVs will mainly depend on their respective costs. Particularly, the research and development of FCEVs will be

accelerated in the next two decades, since they have the good potential to deliver the same range and performance as our ICEVs.

In summary, electric propulsion and energy sources will still be the key technologies to be addressed, EVs and HEVs will still be coexistent, while energy, environment and economy will still be the key issues for EV commercialization. Figure 3 illustrates the development trends of EVs and HEVs. It should be noted that some core technologies can be shared among ICEVs, EVs and HEVs. Our ultimate goal is the use of clean, efficient and intelligent energy to achieve sustainable transportation system for the 21st century.

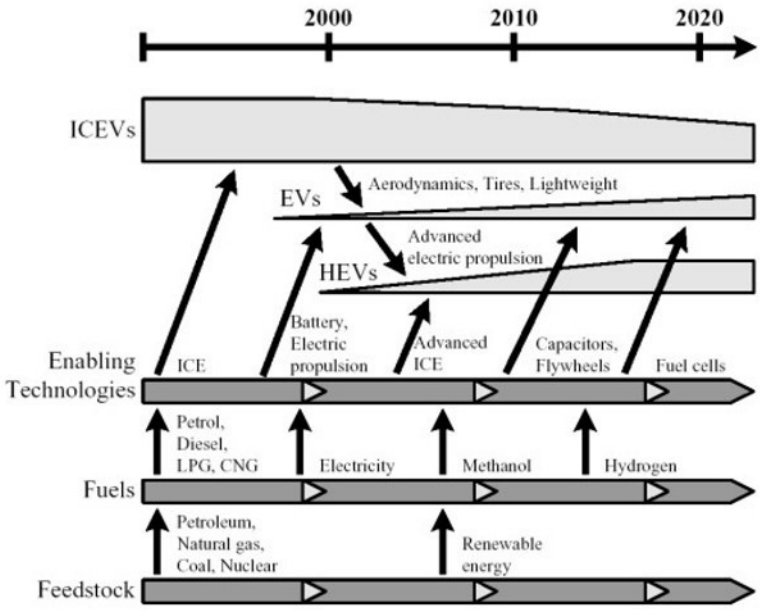


Figure 3. Development trends of EVs and HEVs (Courtesy of EVAA).

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Biographical Sketch

C C Chan received the B.Sc. degree from China University of Mining and Technology, Beijing, China, the M.Sc. degree from Tsinghua University, Beijing, China, and the Ph.D. degree from University of Hong Kong, Hong Kong, in 1957, 1959 and 1981, respectively, and was awarded the Honorary D.Sc. degree from the University of Odessa in 1992.

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