

Comprehensive Analysis of Electric Vehicles: State-of-Arts and Future Aspects

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Abstract. In recent years, developing new energy vehicles has become a crucial approach for nations to address climate change. The United States, the United Kingdom, Japan, Germany, and China have implemented preferential policies for new energy vehicles to boost their development. In addition, several types of batteries and motors for electric vehicles fit diverse situations and market demands. This study extensively explores the major performance and crucial concerns of the key technologies for electrical vehicle application, including battery technologies, motor and pertinent control. Moreover, the future considerations for overcoming the constraints of state-of-arts are presented in this work.

Keywords: Electric vehicles, Topology, Battery, Electric machinery, Electric control.

1. Introduction

In recent years, with the rapid development of the automobile industry and the growing number of automobiles on the planet, there has been an increase in the number of vehicles. The ever-worsening impact of automobiles on the environment has drawn the global community's attention. Reducing pollution and becoming environmentally friendly has been the direction of development for a variety of sectors. In the present automotive industry, the flaws of gasoline cars are becoming increasingly apparent: excessive resource consumption and pollution. Consequently, finding alternate sources of clean energy is the fundamental challenge facing the automotive industry's future. As a result, battery-powered electric vehicles have become a hot topic in the automobile industry in recent years. The electric car is a type of new energy vehicle fueled by a vehicle-mounted battery and propelled by an electric motor that complies with road traffic and safety rules [1]. Pure electric vehicles have the advantages of minimal emissions, low noise levels, less environmental damage than traditional fuel vehicles, and high energy consumption, which makes their development a promising future.

As environmental pollution increased and fossil energy decreased year by year, the environment became increasingly polluted. The considerable deficiencies of traditional fossil energy vehicles, such as high energy consumption and severe pollution, have a significant impact on the lives of individuals. Consequently, electric automobiles have become the dominant trend in the transportation industry. Traditional fossil fuels have been replaced with a varied supply of electricity that can greatly enhance energy conversion efficiency, so that air quality is improved while greenhouse gas emissions are reduced.

The primary components of an electric vehicle's power system are the electric drive system, the power supply system, and the auxiliary system. Components of the electric propulsion system include motors, controllers, power converters, mechanical transmission systems, and wheels. When the motor is operating, the power battery's electric energy will be converted into the wheel's kinetic energy before being used to move it. To recover the braking energy of electric vehicles, during braking, the kinetic energy in the wheel will be transformed into electrical energy and delivered back to the power bank. The controller of an electric drive system is responsible for coordinating and controlling each component, which is analogous to a vehicle's control system. Only when all pieces are well-coordinated can the electric vehicle's best performance be played. As its name implies, the power

supply system for electric cars comprises the battery pack and the battery management system (BMS). The auxiliary system includes a source of auxiliary power, a power steering system, an air conditioner, and a lighting device. The battery pack is the primary source of electric energy in the power system of pure electric vehicles. First, the speed control of the controller and the power converter drive the motor, and then the transmission system drives the wheel to propel pure electric vehicles [2].

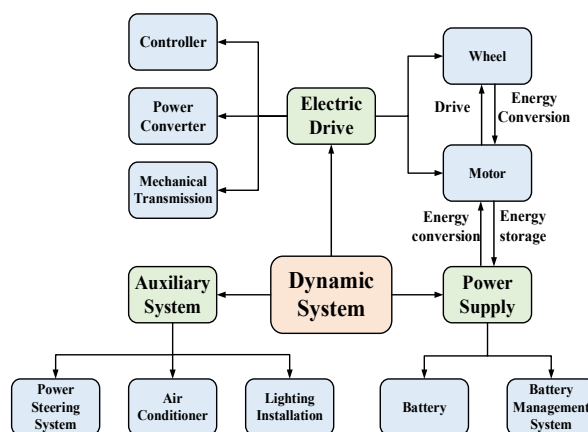


Figure 1. Topology of electric vehicle.

According to the topological structure and internal structure of their transmission system, pure electric vehicles can be separated into centralised drive and dispersed drive. These two variants differ in terms of control operation complexity and assembly organisation to variable degrees [3]. The battery, electric control, and motor of an electric vehicle, etc., is one of the essential aspects of an electric vehicle. Its performance impacts the maximum speed of electric cars, as well as their on-board weight, range, and other vital performance characteristics. There are numerous ways to gather essential information on electric automobiles. However, the majority of the data are general, the material substance is dispersed, and there are few available resources for comprehensive integration and comparison.

Therefore, this paper provides a summary of the evolution of electric vehicles to incorporate the kind of electric vehicle's motor. In addition, it classifies the battery kinds, analyses them, and displays the electric car sensors using the aforementioned data. This article covers the prospects and future development of electric automobiles. This study will conclude by demonstrating that electric vehicles are a relatively green and efficient new energy vehicle that can be produced today, and that their future development prospects are promising.

2. Political support

In Electric vehicles are not only of great significance in solving environmental problems, but also for the development of the automobile industry in all countries, seizing the current development opportunities of electric vehicles will lead the world in the future electric vehicle market [4]. Therefore, all countries in the world are investing a lot of money and technology in new energy vehicles, especially electric vehicles. At the same time, countries have given great support to the development of energy vehicles.

In 2009, after the financial crisis, The Obama administration saw the advancement of electric vehicles as a crucial step toward revitalizing the American auto industry and guiding the country out of its economic crisis. In January 2013, the U.S. government announced a “blueprint for electric Vehicle Adoption”, which aims to improve the market competitiveness of electric vehicles over the next 10 years. In addition, there is a lot of policy support for electric vehicles in the states. For example, California has enacted the zero-emission act, provided subsidies for the purchase of clean cars, made electric cars enjoy public car lanes unconditionally, and provided fiscal, tax and financial incentives to enterprises in the construction of charging piles [5].

In 2008, the UK passed the Climate Change Act, stipulating in the form of legislation that "by 2050, the UK's carbon emissions should be at least 80 percent lower than the baseline level of 1990". This standard in the 2019 amendments decreased to 100% percent again, on the basis of this goal, the electric car policy can be divided into three stages, first of all, in 1995, according to the journal of environmental law and the national air quality strategy, management in the form of air quality through legislation, to provide traffic congestion in the electric and tax breaks. In the second phase, from 2009 to 2016, a number of new environmental laws were enacted, along with low-emission zone exemptions and purchase subsidies for electric vehicles. In the third stage, from 2017 to now, The UK continues to tighten its emission standards and gives more extensive support to electric vehicles [6].

Moreover, Japan passed the Global Warming Act in 1998, making it clear that the whole society should fulfill the obligation of CO₂ emission reduction. At the same time, Japan takes the development of automobile electrification as an automobile strategy to improve the competitiveness of Japanese automobiles. Similarly, the Japanese government also provides subsidies to enterprises and individuals in purchase, taxation, charging pile construction and other aspects [7].

In 2007, the German government launched a comprehensive plan on energy and climate, and put forward electric vehicles as a new direction for future transportation development. In August 2009, the German government officially adopted the National Development Plan for Electric Vehicles, which listed the development of electric vehicles as a strategic task of industrial and national economic development, trying to build Germany into a leading market and supplier of electric vehicles. The German government has made a long-term plan in the research and development of electric vehicles to ensure its leading position in the world. In addition to the above-mentioned same policy preferences, Germany has also made a strategic layout in energy reserve and international cooperation [8].

Table 1. Policies supporting electric vehicles in different countries

Countries	Policies and Measures
United States	2009, Develop electric cars to boost the auto industry. 2013, Blueprint of electric vehicle popularization plan 2019, Set up "Recell" battery recycling center, Oak Ridge National Laboratory, Argonne Laboratory, etc
United Kingdom	1995, Environmental law and The UK National Air Quality Strategy. 2008, Passed The Climate Change Act. 2009, The UK Low Carbon Transition Plan, UK renewable Energy Strategy, UK low carbon Industrial Strategy and Low-carbon transportation strategy. 2013, UK road - side Nox reduction scheme 2018, The Road to Zero.
Japan	2008, An action plan to create a low-carbon society 2010, Next Generation Vehicle Strategy (2010) 2014, Automotive Industry Strategy (2014). 2018, Set up "Automobile New Era Strategy Committee".
Germany	2007, comprehensive Energy and Climate Plan; 2009, National Electric Vehicle Development Plan 2010, Established "Joint Working Group on Promoting Electric Vehicles" 2016, Charging Infrastructure Regulations.
China	2009, Energy Saving and New Energy Automobile Industry Development Plan (2012-2020); 2010, Notice on Launching pilot Subsidies for Private Purchase of New Energy Vehicles 2012, Circular on Tax Policies of Vehicles and Vessels for Saving Energy and Using New Energy

China has mentioned in the "12th Five-Year" Special Plan for the development of Electric Vehicle science and Technology that the establishment of "pure electric drive" technology transformation strategy, continue to adhere to the "three vertical and three horizontal" research and development layout. Preferential policies for electric vehicles in China mainly include cash subsidy policy, vehicle and ship tax exemption policy and encouraging technological innovation policy. Tariff policy for charging facilities, etc. [9]. The following table 1 shows some legislation and policies on electric vehicles in various countries:

3. Battery Technologies For electric vehicles

The development of batteries in electric vehicles can be traced back to 1950s. French physicist Gaston invented lead-acid batteries and the emergence of formal lead-acid batteries has support electric drive vehicles for some practical application, which were originally in the theoretical and experimental stages. The end of the 19th century to the beginning of the 20th century is the first surge period of the vigorous development of electric vehicles. The key to the rise of electric vehicles during this period is the social and economical benefits of fuel vehicles are much less than those of pure electric vehicles at that time. In 1884, Thomas Parker, a British inventor and industrialist, manufactured the first electric vehicle equipped with high-capacity rechargeable batteries [10]. Then, electric vehicles were replaced by gasoline vehicles, and the speed of the development of electric vehicles has slowed down. Until the end of the 20th century, there was no outstanding breakthrough and development in the battery of electric vehicles. Until around 1996, General Motors Corporation of the United States successively launched the first-generation electric vehicle EV1 with the use of lead-acid battery technology and the second-generation electric vehicle using nickel metal hybrid battery as the power source. The automotive industry with electric energy as the driving energy rose again [11]. As lithium-ion battery technology advanced quickly in 2006, particularly due to substantial advancements in safety, it was gradually used to pure electric vehicles and hybrid electric vehicles, challenging nickel metal hybrid batteries. In early December 2014, Spain developed a kind of battery, also known as "super batteries", which attracted the attention of the entire battery industry. In 2015, the University of Cambridge overcame the technical difficulties in the development of lithium air batteries [11], making this technology an important step forward, indicating a new milestone in the research field.

This section will introduce the batteries that are commonly used in electric vehicles from the perspectives of energy density, popularity, usage scenarios, mileage, service life, safety, etc.

3.1 Lead-acid battery

The maximum power rating of a single lead-acid battery is 180W, and its specific energy can reach 170wh/kg at most, with 200~350 charge and discharge cycle times. Generally speaking, the working voltage of lead-acid battery is 2V with a high overvoltage tolerance value and a low self-discharge rate. In addition, the lead-acid battery works well in steady state and the maintenance rate is low as well [10].

Over a century ago, in the 1920s, lead acid batteries first appeared. It is frequently employed as the vehicle's internal combustion engine's starting power source. It is also an advanced battery for electric vehicles. It is widely employed in the power battery of gasoline-powered automobiles and hybrid electric vehicles due to its long history, low cost, abundance of material sources, high specific power, mature technology, and efficient manufacturing process. It is primarily utilized in electric short-distance vehicles including sightseeing cars, battery concept cars, and prototype cars [10]. At present, lead-acid batteries are still widely used in start-up batteries and hybrid electric vehicles, and have achieved good results in energy conservation and emission reduction [11].

Due to the energy depth, the lead-acid battery has a short range of lifetime which would be one and a half years. The lifetime of lead-acid battery is also relatively short among the batteries that can be used today. The use of lead-acid battery will cause more economic losses, due to its short lifetime.

In terms of safety, the use of toxic heavy metal lead in lead-acid batteries will cause environmental pollution and safety problems. In addition, the high requirements of electric vehicles for a wide range of rapid response to current force the application of lead-acid batteries in this field to be limited [12]. Therefore, as a power battery, the future research focus of lead-acid battery is to solve the problems of low specific energy and serious shortening of service life under a high-rate partial charge state.

3.2 Nickel cadmium battery

Nickel cadmium battery was invented by a Swiss engineer, Waldemar Jungner in 1899. The battery uses NiO (OH) as the positive pole and cadmium hydroxide as the negative pole [10]. Generally, the working temperature of nickel cadmium battery is between -20°C and 45°C. Compared with lead-acid battery, nickel battery has a lower energy density. Its working voltage is 1.2~1.4V, and the overvoltage tolerance value can reach 1.7V. In addition, when fully charged, its self-discharge rate is 10% per month. When the temperature is higher than 20°C, its self-discharge rate can reach 20% [10].

The application of nickel cadmium battery is only a little bit less than lead-acid battery, ranked as the second place among electric vehicle batteries, which can be quickly recharged [11]. However, due to the limitations of its specific energy and specific power, nickel cadmium battery remains an application attempt in electric vehicle technology, so it is more used in concept and prototype electric vehicle products [10].

The lifespan of a nickel cadmium battery can reach more than 2000 times, which is more than twice as long as that of a lead-acid battery, but it costs 4–5 times as much. Despite having a high initial purchase price, the long-term actual cost of ownership is low due to the product's benefits in energy efficiency and service life. Nickel cadmium has the drawback of having a "memory effect," which makes it simple to lower the battery's usable capacity due to inefficient charging and discharging. Typically, after using it for around 10 times, it may be fully charged and discharged once [10]. To release memory, it must be fully charged and drained three to five times continuously, albeit, if there is a "memory effect" [11]. Because nickel cadmium batteries are hazardous and similar to lead-acid batteries in terms of safety, recycling them is crucial for their continued use. Numerous research have recently concentrated on the harmful effects of used nickel batteries on humans as well as the separation and extraction of Ni and Cd from used nickel-cadmium batteries [11].

3.3 Nickel metal hydride battery

Nickel metal hydride batteries are alkaline batteries, which appeared in the early 1970s. Its normal operating temperature is between -20~60 °C, the specific power can reach 1200W/kg at a specific discharge depth (such as 50%), the energy density is 420Wh/l, and the number of charging cycles can reach 3000 cycles [12]. Battery capacity 320~450 Ah/kg [10].

Table 2. Comparative analysis of battery characteristics, advantages and disadvantages

Battery characteristics	Lead acid battery	Nickel cadmium battery	Nickel metal hydride battery	Lithium cobalt oxide LCO battery
Energy density	low	Lower	higher	high
Working characteristics	• High overvoltage tolerance value • low self discharge rate • good steady-state working condition	• High overvoltage tolerance	• Low overvoltage tolerance • high self discharge rate	• High theoretical specific capacity • high overvoltage tolerance value
Endurance mileage	short	longer	longer	long
Usage scenarios	Short distance electric vehicles, such as sightseeing cars, battery concept cars, prototype cars, etc	application attempt, concept and prototype electric vehicle products	manufacture of large electric vehicles, not mass produce	mobile devices, such as mobile phones, laptops and electric vehicles
service life	1-1.5 years	2-3 years	5 years	8-10 years
Security	toxic heavy metal, environmental pollution	toxic	Relatively clean and eco-friendly battery, the problem of battery lifetime	green battery, the best battery that can be applied to electric vehicles at present

Nickel metal hydride batteries have been put into the market for production and use in the manufacture of large electric vehicles, but due to the high price, they have not been produced in a large scale.

Nickel metal hydride batteries have greater endurance as compared to lead-acid batteries. One-time charging can provide an endurance range of more than 300 kilometers[11], and its service life is longer than the former. Generally, they can be replaced after using for about five years. However, similar to the previous battery situation, it still does not solve the problem of insufficient endurance of motor vehicles.

Its safety performance is higher than that of the previous lead-acid battery, but the overvoltage tolerance of nickel metal hydride battery is low, and the working voltage is about 1.2~1.5v [10]. One characteristic of this type of battery is its high self-discharge rate, which is about 5% - 20% in the first day and between 0.5% - 4% thereafter [10]. Like other Ni metal batteries, NiMH batteries also have memory effect [10].

The majority of foreign manufacturers of nickel batteries for electric cars are a joint venture between Toyota and Panasonic. The 80Ah and 130Ah cell batteries made by Ovonic have a cycle life of more than 600 times and a specific energy of 75–80Wh/kg. For testing purposes, this kind of battery is put in a number of electric vehicles. One type of vehicle has a range of 345 kilometers on a single charge and has covered more than 80000 kilometers in a calendar year. In China, 55Ah and 100Ah cell batteries as well as nickel batteries with a specific energy of 65Wh/kg and a power density of more than 800Wh/kg have been produced.

3.4 Lithium ion battery

At present, common batteries include ternary (NCM) lithium batteries, lithium titanate (LTO) batteries and lithium iron phosphate (LFP) batteries, the lithium battery described in this section is lithium cobalt oxide LCO battery)

The theoretical specific capacity of lithium-ion batteries is 274Ah/kg, while commercial products are generally 145ah/kg [10]. The average voltage of a single battery is 3.8V, and the charging voltage can even reach 4.4V. The specific energy of batteries in commercial products is 233Ah/kg or even

more [10]. The specific energy of single battery can reach 180wh/kg, while NCA can reach 240wh/kg [10].

LCO batteries are widely used in mobile devices in the market, such as mobile phones and laptops, because of their excellent specific capacity and high energy density [11]. Tesla used these batteries in its roadster electric vehicle around 2008. Since then, the company's models and other pure electric vehicles have adopted this battery technology [12]. Lithium-ion secondary battery is a fresh kind of battery for electric vehicles, which has a wide range of civil and national defence applications because of its unique physical and electrochemical properties [11].

The power storage capacity of a lithium battery is 1.6 times greater than that of a nickel hydrogen battery and 4 times greater than that of a nickel cadmium battery for a given volume and weight, yet humans have only produced and used 20–30% of its theoretical capability [10]. The potential for growth is excellent. In addition, it is a truly green battery that won't harm the environment. It is currently the best battery that can be used in electric vehicles.

China began to develop and utilize lithium-ion batteries in the 1990s, and has made many breakthroughs so far, developing lithium-ion batteries with independent intellectual property rights.

The following table compares and analyzes the characteristics, advantages and disadvantages of several batteries

4. Motor

4.1 Brush DC motor

The main advantages of Brushless DC motor are: small electromagnetic interference, wide speed regulation range, smooth speed regulation characteristics, strong overload capacity, large starting and braking torque, and simple structure [15]. DC motors are used in urban trolleybuses, electric forklifts, electric sightseeing cars and electric patrol cars [13].

It offers exceptional control qualities that are unmatched for an AC motor. DC motors were already extensively utilized throughout the early stages of the development of electric cars. DC motors are still sometimes used nowadays to power electric cars [14]. However, the presence of brushes and mechanical commutators prevents future advancements in motor overload capacity and speed and, if they are used for an extended period of time, necessitates periodic maintenance and commutator and brush replacement [15]. Additionally, the rotor has a loss, which makes it harder to dissipate heat and prevents the motor from improving its torque quality ratio any further. In light of the aforementioned DC motor flaws, as stated in the article "overview of electric car drive motor," some of the new developed vehicle do not use this kind of DC motors.

4.2 AC three-phase induction motor

The most common type of motor is an AC three-phase induction motor. The silicon steel sheets that make up the stator and rotor are bonded together, and the stators don't come into touch with any sliding rings, commutators, or other parts [15]. durable construction, dependable operation. The AC induction motor's power range is very broad, and its maximum speed is between 12000 and 15000 rpm. With great cooling freedom, air cooling or liquid cooling can be used [14]. It can use regenerative feedback braking and has strong environmental flexibility [15]. The efficiency is higher, the weight is lowered by about half, the cost is lower, and the maintenance is easier when compared to a DC motor of equal power [13]. As stated in the article "overview of electric vehicle drive motors", AC three-phase induction motors generally use vector control or direct torque control frequency conversion speed regulation control mode, which makes them have better dynamic and static characteristics compared with DC brushless motors [15].

4.3 Permanent magnet brushless motor

A high-performance motor is a permanent magnet brushless motor. There are two different types of permanent magnet synchronous and square wave motor control systems for AC permanent magnet

brushless motors [15]. Permanent magnet synchronous motors are controlled using the vector control technique, and permanent magnet brushless square wave motors are controlled using a technique akin to that of DC motors [14]. The mechanical contact structure with the outward characteristics of a DC motor without a brush is its most distinguishing feature. The heated armature winding is installed on the outer stator, which makes it simple to dissipate heat. Additionally, it uses a permanent magnet rotor without excitation loss. As a result, the permanent magnet brushless DC motor has a long lifespan, reliable capability, and minimal maintenance [14]. It also has no commutation spark and no radio interference. Its speed is also not constrained by mechanical commutation. It can rotate at a speed of hundreds of thousands of revolutions per minute if air bearings or magnetic bearings are utilized. It has a fair chance of finding use in electric cars because it is more efficient and has a higher energy density when compared to permanent magnet brushless DC motor systems [15]. As stated in the article "overview of sensorless control methods for permanent magnet synchronous hub motor of electric vehicles", for the problems of poor smoothness of motor starting, small starting torque, and abnormal starting of rotor reverse rotation caused by inaccurate position information, this paper adopts permanent magnet brushless motor, and uses zero speed and low speed sensorless control methods, so that it has low cost and good robustness.

Table 3. Advantages and disadvantages of four motors

	Brush DC motor	AC three-phase induction motor	Permanent magnet brushless DC motor	Switched reluctance motor
merit	1 wide speed regulation range and smooth speed regulation characteristics; 2. strong overload capacity, large starting and braking torque, and simple structure. 3.urban trolleybuses, electric forklifts, electric sightseeing cars and electric patrol cars	1. Simple structure, reliable operation and durability; 2.wide power coverage of AC induction motor 3.Air cooling or liquid cooling can be adopted, with high cooling freedom 4.High efficiency, low price and convenient maintenance	1.no commutation spark; 2.No radio interference; 3.Long service life, reliable operation and simple maintenance	1.simpler structure, no phase-to-phase jumper wire; 2.wide speed regulation range, flexible control, and high efficiency in a wide range
demerits	1. Wear it quickly, and the brush DC motor wears faster; 2. Arc between brush and commutator. electrical noise; 3.imited maximum speed of brush DC motor	1.low value of the motor, the reduction of motor efficiency; 2. difficult realization of the speed control, small speed change of motor; 3. high input surge current	1.Torque; 2.With the increase of speed, commutation leads to the intensification of torque ripple and the significant decrease of average torque.	1. torque ripple, the low-speed operation performance of SR motor

4.4 Switched reluctance motor

A novel kind of motor is a switched reluctance motor. The structure of this system is simpler than any other motor, which is just one of several evident characteristics. The motor's rotor is devoid of slip rings, windings, and permanent magnets, while the stator is covered in straightforward focused windings. It is simple to maintain and repair since the end of the winding group is short, there is no phase jumper, and [15] As a result, the speed can exceed 15,000 r/min, and the reliability is good. The efficiency can be higher than that of an AC induction motor, between 85% and 93% [15]. The stator is where most of the loss occurs, so cooling the motor is simple. The permanent magnet rotor element also has a wide speed regulation range and flexible control, making it simple to realize the torque speed characteristics of various special requirements while maintaining high efficiency over a wide range of speeds. For the power performance requirements of electric vehicles, it is better suited [15].

Table 3 compares and analyzes the characteristics, advantages and disadvantages of several motors.

5. Electric control

The pure electric vehicle's electronic control system is its brain, and it is made up of a number of subsystems, each of which typically includes sensors, a signal processing circuit, an electronic control unit, a control strategy, an actuator, a self-diagnosis circuit, and an indicator light. The electric control systems of various types of electric vehicles vary slightly, but generally speaking, they consist of the energy management system, regenerative braking control system, motor drive control system, electric power steering control system, and powertrain control system, etc. The functions of each subsystem are not simply superimposed, but integrated to control the electric vehicle. It is divided into energy management system, regenerative braking control system, electric power steering system, powertrain control system.

Energy management system is the core of multi-energy electric vehicles. It is divided into power distribution, power limitations and charging control. Its functions include maintaining all battery components of electric vehicles and making them in the best state. Collect the operation data of each subsystem of the vehicle for monitoring and diagnosis; Controls the charging method and provides a display of remaining energy.

The regenerative braking control system can convert the traction motor into a generator when the electric vehicle is braking, and rely on the wheel to drag the motor to generate electrical energy and wheel braking torque, so as to slow down the speed of the vehicle while converting part of the kinetic energy into electrical energy storage.

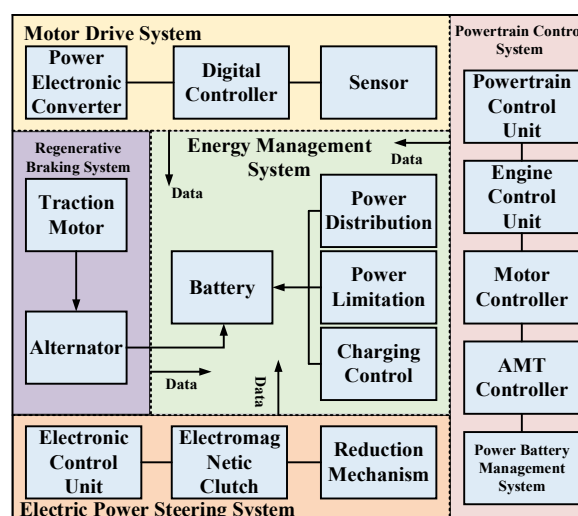


Figure 2. Electronic control structure of electric vehicle

The motor drive system is mainly composed of motor, power electronic converter, digital controller and sensor. It matters whether electric cars can operate safely and reliably.

Electric power steering system is usually composed of sensors, electronic control units, motors, electromagnetic clutches and reduction mechanisms. Through clutch and deceleration mechanism, the auxiliary power is applied to the steering system, so as to achieve real-time control of power steering.

Powertrain control system includes powertrain control unit, engine electronic control unit, motor controller, AMT controller and power battery management system. It ensures the smoothness of the shift operation. [16]

6. Development prospect of electric vehicles

6.1 Further strengthen the research of drive motor

The United States prefers to use AC induction motors, despite the fact that they have considerably more difficult controller technology, they have the benefits of simple structure, great performance, and low quality; Japan typically opts for permanent magnet brushless DC motors, which have the advantages of high efficiency and low weight but have the drawback of being relatively expensive and exhibiting the issue of high temperature demagnetization; In recent years, Germany and Britain have put a lot of work into developing switching reluctance motors. It has inexpensive cost and a simple structure as positives, but rather loud noise is one of its drawbacks. Chinese researchers are now working on switching reluctance motors and rare earth permanent magnet brushless DC motors, both of which need to be extensively employed in the future.

6.2 Transition from hybrid to pure electric vehicle

Pure battery electric vehicle industrialisation and large-scale development lag considerably because of the impact of battery performance. Because of this, hybrid electric cars progressively develop into internal combustion engine vehicles and intermediate forms of pure electric vehicles that not only have the benefits of internal combustion engine technology but also fully exploit the benefits of motor drive. With the aid of a sophisticated management system, a hybrid electric vehicle combines the internal combustion engine and energy storage components now in use. This may significantly cut fuel consumption and pollutants, and the cost is quite modest

6.3 The ultimate goal is fuel cell vehicles

Particularly the electric car, whose creation and fuel replenishment times are significantly longer than those of conventional batteries, in terms of both cost and real performance. The methanol, natural gas, and other fuels used by the fuel cell come from a variety of sources and are also renewable energy, It got going once fuel cell car research was successful. Additionally, the fundamental issues with electric vehicle technology that must be resolved in the future can significantly lower the cost of production, encourage the expansion of battery capacity, and expand the range. Unavoidably, the public fast charging station will play a significant role in the future commercialization of electric vehicles. To ensure the long-term growth of pure electric vehicles, it must be significantly enhanced. The development of pure electric cars will unavoidably be hampered if the charger and on-board battery cable connectors are not standardized in order to assure that all batteries are of the same kind, voltage, and power. These issues must be addressed and are addressed by government agencies. Pure electric car charging stations, cables, connectors, and invoicing systems are all crucial components. The development of electric vehicles will unavoidably be hampered if these contents are poorly done. The suppliers of the necessary parts must also come together to create a flawless manufacturing chain. Pure electric vehicles can only emerge quickly in our nation if these issues with electric vehicles are actually solved at this point.

7. Summary

This research seeks to comprehend the current status of the development of new energy electric vehicles, covering all types of batteries and sensors used in electric vehicles, as well as electronic control and motor systems. This article examines the development prospects of electric vehicles in the current environment, as they provide numerous advantages over conventional fossil fuel automobiles. howbeit traditional internal combustion engine machineries begin for overlook a market, supporting those development as regards simple in decay-free electric tools are always be an unavoidable industry development trend. Moreover, governments give tremendous emphasis to this matter. Even if we have collected considerable expertise in product technology and market development for the commercial development of electric vehicles, there are still a great number of

issues to be resolved at this level. These issues require the collaboration of technicians from various nations and the cooperation of government agencies. It is anticipated that electrical, mechanical, and control technologies will be used to drive automobiles in the future, and that electric vehicles will become the predominant mode of transportation.

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