Review on Electric Vehicle

[1]Shubham Pralhad Rajput, [2]Mangeshkumar S. Jadhav

[1]Department of Mechanical Engineering, Dr.Vishwanath Karad WPU-Pune, India.

[2]Professor, Department of Mechanical Engineering, Dr.Vishwanath Karad WPU-Pune, India.

Abstract

Electric Vehicle have been a subject of research since 1800's, but the studies based on Electric Vehicles have witnessed booming growth, as the rate of fuels increasing day by day and awareness about air pollution caused by conventional IC engine vehicles. Electric vehicles are non-polluting and can be termed as Green transportation. It's a new trend in automotive industry to develop environment friendly vehicle. The aim and objective of this review article is to methodically study and understand the modelling and working of Electric motor & battery for an Electric Vehicle and further advancement to be made in the same.

Keywords: *Electric vehicles (EVs), Internal combustion engine(IC engine), Electric Motor, Batteries.*

1. Introduction

The traction effort required for driving of electric vehicle is developed by an electric motor rather than an IC engine in conventional vehicle. This motor is powered by an electric battery. The research on EVs is continued from long time but it's now entered in third century as a commercially available product and also becoming popular among the costumers. Today awareness about the environment, exhaust emissions, developed a need to new developments in batteries and fuel cells to make advancement in EV technology. EVs are treated as zero emissions vehicle and are much environment friendly than the other conventional fuels like gasoline or LPG powered engines. EV consists mostly of electronic components rather than conventional automobiles consisting majority of mechanical components, which makes it minimal on maintenance. EVs do not consist of ICEs in them, means there are no oil changes and there is no tail-pipe emissions and hence are also far more energy efficient and quiet in operation.

There have been a lot of research and development in this field. The first EV was built by T*homas Davenport* in the U.S. in 1834. In 1847 *Moses Farmer*, built the first two-passenger EV. At that time there were no rechargeable electric battery cells, then Frenchmen *Gaston Plante* and *Camillie Faure* respectively invented this technology in 1865 and improvements were done in 1881 in the storage battery.

The major parts of an EV are electric battery for storage of energy, an electric motor for traction force development, and a controller. The battery can be normally charged from mains electricity via a plug and a battery charging unit that can either be carried onboard or fitted at the charging point.

This paper includes details about Electric vehicle technology, its components, case study about modelling & conclusion.

2. Need of Electric Vehicles (EVs)

One of the greatest achievements of modern automobile technology is the development of internal combustion engine vehicles i.e. automobiles. But these vehicles consume hydrocarbon based fuels for their propulsion. These hydrocarbons on combustion produces many toxic products which have caused and causing serious problems for environmental and human life such as air pollution, global warming and rapid depletion of limited petroleum resources.

In last few decades, the research and development activities related to transportation are significantly focused on the development of high efficiency, clean, and safe transportation. The proposed vehicles which can replace existing conventional ones in future are electric vehicles, hybrid vehicles and fuel cell vehicles.

2.1 Air pollution

As of now, all the vehicles depend on the combustion of hydrocarbon based fuels which produces tail-pipe emissions due to improper combustion. The ideal combustion should only produce carbon dioxide and water, but it is never ideal. Hence after actual combustion its product contains certain amount of Nitrogen-oxide (NOx), Carbon monoxides (CO), unburnt hydrocarbons (HC) and some particular matters which are toxic and dangerous for human health.

2.2 Global Warming

The presence of carbon dioxide and other gases such as methane, in the atmosphere results in greenhouse effect which is the main cause for global warming. The

Sun's infrared radiations reflected by the ground are trapped by these gases, due to which the temperature of earth is increasing.

2.3 Petroleum resources

Oil resources of the earth are limited and how long they will last completely depends on new discovery, oil production and their controlled combustion use. Data from resources shows that the new discovery of oil resources occurs slowly while the consumption shows a high growth rate, as shown in Fig 2.3. If oil discovery and consumption continues as current trends, the world oil resource will last by 2038.

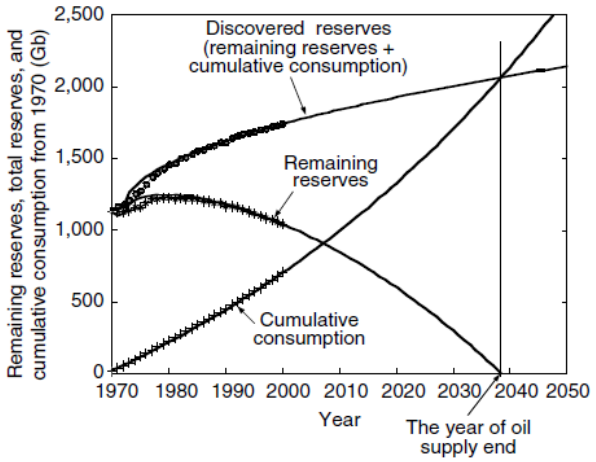

Fig 2.3 Oil discovery, Consumption and remaining resources
Source: (M. Ehsani, *Modern Electric, Hybrid Electric and Fuel Cell Vehicles: Fundamentals, Theory and Design*, CRC Press, 2005.)

3. Types of EVs

There are three main types of electric vehicles, according to limit to which their operating is desired to the use the source of energy as electricity.

3.1 Battery Electric Vehicle (BEV)

The BEVs are only powered by electricity not in company with IC engine; therefore they are known to be the only zero tail pipe emission type. For recharging they have to be plugged into electric power grid. Generally BEVs are not equipped with gearbox because of their totally electric drive train.
Present examples of BEVs are Tesla's products such as Model S or Model X , Mahindra's Products like e2o, e-verito available in India.

Advantages:
Zero tailpipe emissions.
No need of fuels like petrol or gas.
It can be easily recharged at home.
Cost of operation is lower.

Disadvantages:
Its range is limited than petrol operated vehicles.
Initial cost is high.

3.2. Hybrid Electric Vehicle (HEV)

HEVs are powered by IC engine as well as electricity. IC engine is primary source for propulsion and electric motor is secondary. Hence HEVs are equipped with small battery. Engine or regenerative braking provides the power to it. This battery cannot be charged by plugging in to power grid because of its small capacity and they are not having such provisions.
The Honda Civic Hybrid and Toyota Camry Hybrid both are examples of HEVs.

Advantages:
Its range is longer range than BEV
Less fuel consumption than conventional vehicle

Disadvantages:
Still produce emissions
Complex mechanism= Gasoline + Electric
No ability to conveniently charge at home

3.3. Plug-in Hybrid Electric Vehicles (PHEVs)

PHEVs also have IC engine along with electric motor as that of HEVs. But the main difference is the method of charging where besides the energy from engine and regenerative braking battery can be charged by plugging in to power grid. Hence batteries are of bigger size and drive the vehicle to several kilometres; and after discharge, IC engine takes the charge. This fact helps PHEVs to drive for longer range.

Advantages:
Its range is longer than BEV
Consumes less fuel as compared to conventional
Emissions are minimized as compared to HEVs

Disadvantages:
It produces tailpipe emission
Frequent fuel and oil changes are required
Needs fuel and oil changes
These are more costly to operate than BEV but less than HEV

4. Main components of an EV

Electric vehicle is one of the best emerging technologies for environment friendly transportation by reducing the emissions caused by fossil fuels. Electric motor, converters, controller, battery are the major components of an EV. The following is a block diagram of power flow in an electric vehicle as shown in Figure 4.1

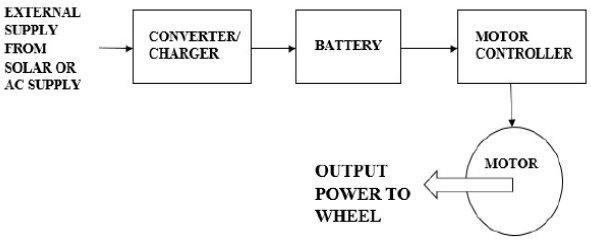

Fig 4.1.Power flow in an EV

4.1 Electric Motors

Electric motor acts as an engine in case EV, which delivers the power required for traction. Various types of motors are available; hence proper selection of motor is important for desired output.

4.1.1 DC SERIES MOTOR

The DC series motor comes under self-excited type as its field winding is connected in series with the armature winding. This type has brushes and mechanical commutation. High starting torque is the main advantage of DC series motor and at this condition it draws less current and power. Its torque is directly proportional to current ($T \alpha I^2$) makes it suitable for traction purpose. Its disadvantages are that the speed regulation is poor and it has to be loaded before starting. The lifetime is also short.

4.1.2. Induction motor

Working of Induction motor also known as asynchronous motor is based on the *Faraday's* law of electromagnetic induction. As the stator winding are excited by external source causes the interaction of stator and rotor hence the rotation of motor. Squirrel cage induction motors are mostly used. Simple construction, less cost and less maintenance makes them suitable for EV. As there is no brushes which produce spark hence can be used in presence of water and explosive environment. Self-starting is their main property. Difficulty in speed control is the disadvantage and they have higher copper loss and hence efficiency is low.

4.1.3. Permanent magnet motor

In this type of motor the rotating speed of stator and rotor is same. In PM motor the permanent magnet replaces the field winding. These motors are also termed as PMAC (Permanent Magnet AC motor) if powered by AC supply. High efficiency and higher torque density are the advantages. If it is powered by DC supply then known as permanent magnet DC motor or Brushless DC motor. The advantages are they are smaller in size, and have no field windings hence the losses are less and efficiency is high. Higher cost than AC induction and DC series motors.

4.3. Battery

Battery is source of power for an EV just like fuel tank in IC engine vehicles. Battery is made up no of cells joined together. The function of battery is to convert stored chemical energy into electric energy. A single battery cell is made of two electrodes one is a negative electrode and other is a positive electrode which are connected by an electrolyte. Electricity is generated by the chemical reaction between the electrodes and electrolyte. By reversing the current the chemical reaction can be reversed in rechargeable batteries. Thus by this way battery can be recharged. The battery specifications are determined by the type of materials used for electrode and electrolyte. Various types of batteries are available and some are under development stage for the EV application. Some of these batteries are as follows.

4.3.1 Lead-acid battery

It is one of the oldest battery type used from a long period in automobiles. Its low cost, relative high power capability and good cycle are its advantages. In HEVs high power is first criteria hence it finds its application in HEVs. The cost of its materials involved (lead, lead oxide, sulfuric acid) is low as compared with others. Its disadvantages are lower energy density because of higher molecular weight of lead. As its temperature characteristics are poor so below 10°C, its specific power and specific energy are reduced. Because of this parameter the application of lead-acid batteries for the traction of vehicles operating in cold climates is difficult.
The chemical reaction is given as:
$Pb + PbO2 + 2H2SO4 \longleftrightarrow 2PbSO4 + 2H2O$

4.3.2 Nickel Metal Hydride

This battery type uses nickel in the positive electrode of battery. The battery uses hydrogen absorbed in a metal hydride at the negative electrode. Nickel oxyhydroxide becomes nickel hydroxide during discharge. At the negative electrode hydrogen is released from the metal producing water and electrons during discharge. Ni-MH battery does not use cadmium and is therefore environmental friendlier. Its nickel content makes recycling profitable. But its service life is limited.
The overall reaction is written as:
$MH + NiOOH \longleftrightarrow M + Ni(OH)2$

4.3.3 Lithium-ion

Lithium-ion batteries are becoming popular among the EV manufactures. Because of its inherent properties like more energy capacity in lighter pack, better temperature performance, rapid charging, low self-discharge rate and low maintenance. As its high energy density it covers more distance per charge. Cost and short life are the major drawback of Li-Ion batteries. The available EVs such as Tesla Roadster, Nissan Leaf and Mahindra e-Verito, e2o are equipped with Li-ion batteries.

The chemical reaction is as follows:
LixC_Li1_xMyOz ↔ C_LiMyOz.

Comparison of different battery chemistries:

Chemistry	Cell Voltage(V)	Energy Density (Wh/Kg)	Power Density(W/Kg)	Cost ($/kwh)
Lead-acid	2.2	30-50	180	200
Ni-MH	1.2	60.120	250	750
Li-Ion	3.6	110-160	340	1000

4.4 Motor controller

The controller takes all essential inputs from sensors and regulates the movement of the motors. It controls amount of power that motor draws from the storage batteries to regulate the torque generated by motor. Controller functions similar to carburettor or fuel injection system in IC engine vehicles. It can include means for starting or stopping the motor, choosing forward or reverse rotation, controlling the speed etc. Controllers also have system to obtain energy during regenerative braking.

4.5 Converter

4.5.1 DC to DC converter

In order to run vehicles 12 volt accessories it is required to provide a separate battery or DC to DC convertor. The DC to DC convertor steps down the voltage level required for applications such as headlights, horns etc.

4.5.2DC to AC converter

The main supply from a battery is a DC supply while some motors may require AC supply. So it is required to convert this DC into AC of equivalent frequency and magnitude. For this purpose DC to AC convertors are used.

5 .Case study

Objective: To understand modelling of Electric motor

Fig 5.1 Understanding the vehicle dynamics:

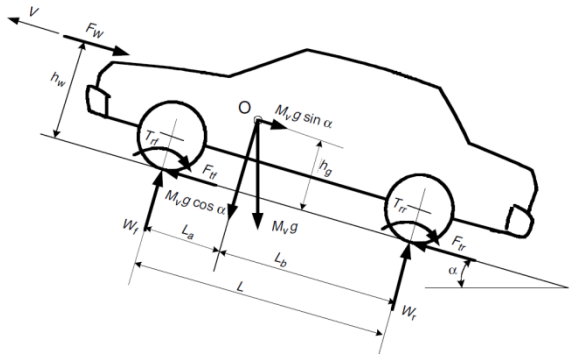

Fig. Source :(Internet)

According to Newton's second law
$M a = m \frac{dv}{dt} = F_{tractive} - F_{resistive}$

5.2. Power rating based on vehicle dynamics:

To determine the power rating of a vehicle, the vehicle dynamics like rolling resistance, gradient resistance, aerodynamic drag, etc. are considered. To demonstrate the procedure for selecting motor rating for an electric vehicle of gross weight 800 kg is considered.
For this demonstration we will consider,
C_{rr}=0.01 M= 800 kg V=100km/hr.
Where,
C_{rr}= Coefficient of rolling resistance
M= Weight of vehicle in kg
V= Speed of vehicle in km/hr

5.2.1Total tractive force is given as:
$F_{total}=F_{rolling} + F_{gradient} + F_{aerodynamic\ drag}$

Where,
F_{total} =Total force required for traction
$F_{rolling}$= Force required to overcome rolling resistance
$F_{gradient\ resistance}$= Force required to overcome gradient resistance
$F_{aerodynamic\ drag}$=Force required to overcome aerodynamic drag
F_{total} = Total tractive force required in order to move the vehicle.

5.2.2 Rolling resistance
$F_{rolling}$=Crr*M*g
$F_{rolling}$= 0.01*800*9.81=78.48 N
$P_{rolling}= F_{rolling}*V/3600$= 78.48*100/3600= 2.18 kW

5.2.3Gradient resistance
$F_{gradient\ resistance}$=M*g*sin α
In this demonstration, considering the electric car runs on a flat ground. Therefore, the angle α =0^0.
Fgradient= 450*9.81*sin 0^0= 0 N.
Hence power required to overcome grading resistance is also zero.

5.2.4. Aerodynamic drag
$F_{aerodynamic\ drag}$= 0.5*CA*Af*ρ*$(Vo)^2$
Assume the power required to overcome aerodynamic drag as 1.3 kw.
So the total tractive power required is
P_{total}= 2.18 kW +1.3 kW= 3.48 kW

Assuming the efficiency of system is 0.85. Hence actual mechanical power output($M_{tractive}$) to drive the vehicle :

$M_{tractive} = P_{total} / \eta$

$M_{tractive}=P_{total}/\eta$=3.48/0.85 = 5 kW (approx.)

From this demonstration for 800 kg vehicle we have calculated a motor of rating 5 kW.
After studying different motors characteristics a 5 kW Brushless DC motor is selected as the traction motor

for an electric car of load 800 kg. The excitation voltage is selected as 48V for the Brushless DC (BLDC) motor.

6. Future

The driving range of EV is totally depends on battery. If more research is done on new technologies like Li-ion, Li-ion phosphate or Fuel cell and ultra-capacitor the range of EV can be increased. Fuel cell will be used. If the developers of EV can decrease charging time to few minutes and provide adequate charging stations, then market is wide open to EV.

7. Conclusion

The growth of electric vehicles industry is more rapid in last few years due to awareness about environmental concerns and air pollution. And EVs own characteristics make it suitable alternative for future and improvements in technology will decide its growth.

References

1) M. Ehsani(2005), Modern Electric, Hybrid Electric and Fuel Cell Vehicles: Fundamentals, Theory and Design, *CRC Press.*

2) A.K.Sawhney(2015),"Electrical Machine Design", *Dhanpat Rai Publications.*

3) EMMA ARFA GRUNDITZ, 'Design and Assessment of Battery Electric Vehicle Powertrain, with Respect to Performance, Energy Consumption and Electric Motor Thermal Capability '

4) Rony Argueta(2010), "The Electric Vehicle," Technical Report, University of California Santa Barbara College of Engineering.

5) T.Porselvi1, Srihariharan .M. K , Ashok.J, Ajith Kumar.S (2017), 'Selection of Power Rating of an Electric Motor for Electric Vehicles', *IJESC.*

6) Ramesh C. Bansal (2005) "Electric Vehicles", Depatment of Electrical and Computer Engineering, BITs Pilani.