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Motors and Batteries for Electric Vehicle: A Review

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A B S T R A C T

The development of electric vehicles has been improving day by day, Electric cars are predicted to be the next disruptive market force for transportation and technology, because of oil shortage and the impact of greenhouse gaseous released from the internal combustion engine vehicles to the environment. Today's need for clean energy and the need to reduce carbon dioxide emission from internal combustion engines. Electrical vehicles are clean and They have the potential to revolutionize how energy is used, created and redirected. Therefore, these vehicles replace the conventional internal combustion engine with electric motors. Electric vehicle has so many components but apart from that motors and Batteries are Important components. In this paper, a review discussed about different electric motors with respect to their design simplicity, cost, ruggedness and efficiency and the various batteries required for Electric vehicle is presented.

Keywords: Electric Vehicle, Motor, Battery, BLDC, PMSM, ICE

1. INTRODUCTION

Electric vehicles (EV's) have been around since before the tum of the century. They were very popular and sold reasonably well until about 1918.

However, the use of EV's for transportation died out as the gasoline powered internal combustion engine (ICE) continued to improve By 1933, the number of EV's was reduced to nearly zero because the EV was slower and more expensive than its ICE counterpart. The shortcomings which caused the EV to lose its early competitive edge have not yet been totally overcome. Significant advances in power electronics and microelectronics have been utilized to make EV powertrains that provide performance competitive with ICE powertrains. Although there have been no similar advances in battery energy storage, the evolution of materials and production technologies provide means to achieve the optimistic battery system goals.[1]

Due to public attention of the limited amount of fuel energy in the world and the emission of greenhouse gaseous by the internal combustion engine vehicles, people started to look for environmentally friendly vehicles that can be powered using alternate rechargeable energies. As electricity is one of the sustainable energies, the concept of vehicles using electricity to power up the car was introduced. Although electricity is the sustainable energy to power up the motors of the vehicles, the concept of an electric vehicle was not introduced to the world until the year of 1859. In the same year, the rechargeable battery named lead-acid battery was first conceived by Gaston Planté . Batteries play an important role to the evolution of the electric vehicles as it is a must for the electric vehicles to carry a portable item that stores electricity in order to have the electricity supply to its motor.[2]

Typically, an electric motor consists of a rotor, stator, windings, air gap and commutators/converters. Depending on different arrangement of these components different types of electric motors are constructed Those electric motors that do not require brushes for commutation or energy conversion are called brushless permanent magnet motors. Furthermore, motors can be categorized according to the shape of their back-EMF. Their shape can either be sinusoidal or trapezoidal. Based on these shapes, they can be Permanent Magnet AC Synchronous Motors (PMSM) or Brushless DC motors (BLDC) respectively.[3]

For an Electric motor to be successfully deployed as the drive for EVs, it should be highly efficient, it should have great power density and should be costeffective. However, the specification of the motors depends on its application purpose. This application could range from home, regular vehicular and heavyduty vehicles. Furthermore, the performance of motors depends mainly on vehicle duty cycle, thermal characteristics and the cooling mechanism

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implemented. The classification of various motors used in traction is shown in Figure 1. A brief literature review on the motors used for traction in EV/HEVs is presented below. In this work, literature review of both AC motors and DC motors is presented looking at the features mentioned earlier.[3]

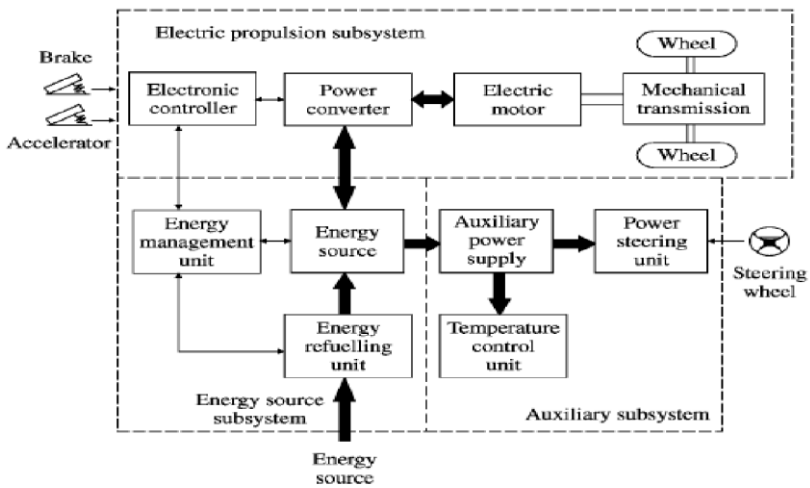

Fig 1: Block of diagram of electric vehicle [3]

II. EV Batteries

A. TRACTION BATTERY

Traction battery was one of the most important components of the electric. Mainly road vehicles, locomotives, industrial trucks and mechanical handling equipment use the traction batteries as power resources. It is also possible to refer to the rechargeable traction battery as the electric vehicle battery (EVB). The traction batteries, unlike the auxiliary batteries support the entire electric vehicles instead of just providing the energy needed to start the engine for the vehicles. The lead-acid battery, the nickel-cadmium battery (Ni-Cd), the nickel-metal hydride battery (NiMH) and the lithium are examples of the major traction batteries.[2]

B. LEAD-ACID BATTERY

Lead-acid battery was invented in 1859 by Gaston Planté as the world's first rechargeable traction battery. The lead-acid was the first type of rechargeable battery in the world that was commercially used especially in the industry of automobiles. The lead-acid battery was modified by Camille Alphonse Faure in 1881 and the performance and capacity of the modified lead-acid battery has improved by using the lead grid lattice. The manufacturing processes of the lead-acid batteries were also made easier after the modification of lead-acid batteries by Camille Alphonse Faure. Although the lead-acid battery was invented 160 years ago from 2019, it is still contributing widely in the field of automobiles considering its cheap cost [2].

C. NICKEL CADMIUM BATTERY (NICD)

Nickel Cadmium Battery has been widely used by the society and intended to replace lead-acid battery especially the automobiles manufactured in Europe. The usage of Nickel Cadmium battery in the electric vehicles is developed in 1980s and 1990s. The Nickel Cadmium battery is well known for its good battery cycle life. Unfortunately, due to its relatively low range and uncompetitive selling price, the market of Nickel Cadmium battery did not expand [2].

D. NICKEL METAL HYDRIDE BATTERY (NIMH)

The usage of hydrogen inserted in metallic alloys instead of cadmium at the negative electrode, the Nickel Metal Hydride battery is considered an advanced version of the Nickel Cadmium battery. The Nickel Metal Hydride battery is constantly sealed to prevent hydrogen from leaking. Due to the Nickel Metal Hydride battery's significant improvement in energy density, it replaces Nickel Cadmium in the application of electric vehicles. The usage of Nickel Metal Hydride battery did not get commercialized in the 1990s as the newer technologies of battery were introduced very soon after the Nickel Metal Hydride was developed [2].

E LITHIUM-ION BATTERY

Rechargeable lithium-ion batteries were developed and introduced in the 1990s to the world with a significant weight advantage over other battery systems. Lithium-ion battery, known as one of the most outstanding quality in the new electrochemical industry. It is one of the most used and widespread batteries used by electric vehicles today [8]. The Lithium-ion battery's weight advantages make it competitive with other battery systems. Because of its high specific energy, the lithium-ion battery has a relatively greater travel distance, which is about three times greater than the mileage of the lead acid battery [9]. In the automotive industry, the Lithium-ion battery has obvious advantages as it has a long cycle life, high energy capacity and high efficiency. Lithium-ion batteries are extremely likely to contribute more to the current markets and the lives of people as the development of new products, innovations and strategies continues to advance.[2]

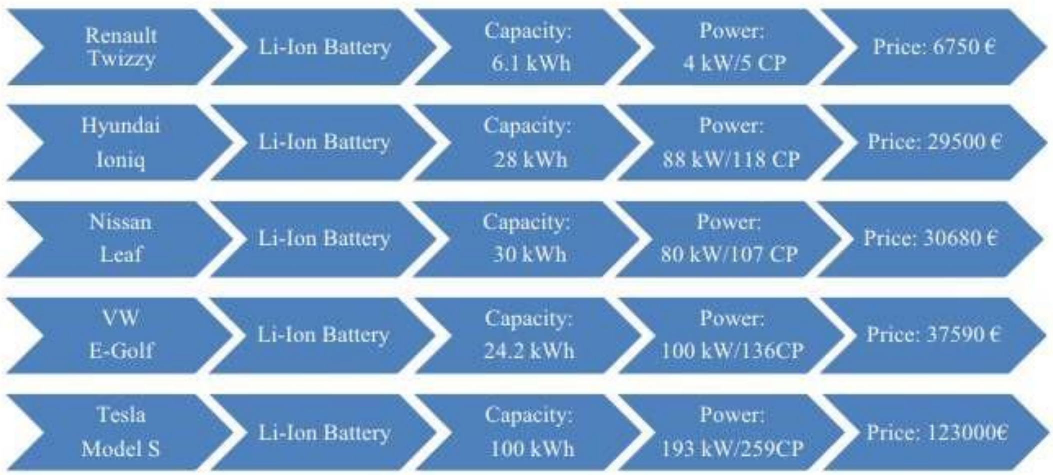

Fig 2. Comparative evaluation of different electric vehicle market cost.[4]

III. Motors for EV

A. Permanent Magnet Synchronous Motor (PMSM)

This motor shares some similarities with the BLDC motor, but is driven by a sinusoidal signal to achieve lower torque ripple. The sinusoidal distribution of the multi-phase stator windings generates a sinusoidal flux density in the air gap that is different from BLDC motor's trapezoidal flux density. This motor possesses feature of an induction motor and a brushless dc motor. The motor has a permanent magnet rotor and winding on its stator. Furthermore, the stator of this motor is designed to produce sinusoidal flux density which resembles that of an induction motor. The power density of this motor is higher than induction motors with the same ratings since there is no stator power dedicated to magnetic field production. Today, these motors are designed to be more powerful while also having a lower mass and lower moment of inertia. This motor can generate torque at zero speed, highly efficient and produces high power density compared to an induction motor. However, this motor requires a drive to operate. To achieve the specifications of high torque at low speed, high density and high efficiency, this motor uses variable frequency drive. However, the VFD control technique increases the complexity of the system and hence requires careful attention to precisely control its speed. Hence the cost of this motor is on the higher side as compared to the induction motor. [3]

B. The Stepper Motor

The stepper motor and switched reluctance motor have the same structure. The stator of a stepper motor consists of concentrated winding coils, while the rotor is made of soft iron laminates without coils [19]. Torque is produced in these motors when the current switches from one set of stator coil to the next coil, the switching currents from stator windings generates magnetic attraction between rotor and stator to rotate the rotor to the next stable position, or "step" [20]. The rotational speed is determined by the frequency of the current pulse, and the rotational distance is determined by the number of pulses. Since each step results in a small displacement, a stepper motor is typically limited to low-speed position-control applications. The ability to move a specific step makes these devices commonly used in positioning mechanisms. Stepper motors are characterized by their moving and holding torque which if exceeded the motor slips and hence the motor loses count. This motor produces torque through magnetic reluctance, magnetic attraction or both. The motor doesn't offer dynamic speed control. The motor can only be accelerated at full toque to full speed and decelerates at full torque. Hence, the motor offers greater torque for a given speed. Therefore, this motor is ideal for precision and position control purposes, making it unsuitable for EV application.[3]

C. The Switched Reluctance Motor

The rotor in the Switched Reluctance motor (SR) cannot generate magnetic field around itself because of the absence of coils in the rotor, therefore no reactive torque is produced in an SR motor. Torque in these motors is produced when a stator phase is energized, the stator pole pair attracts the closest rotor pole pair toward alignment of the poles. This way, high-torque ripple is generated which contributes to acoustic noise and vibration. However, due to its simple design, SR motor is very economical to build, and is perhaps the most robust motor available [20]. This motor relatively produces lower torque compared with the stepper motor. Hence, its use is not popular in EV application.[3]

D. Brushed DC motor

A brushed DC motor consists of a commutator and brushes that convert a DC current in an armature coil to an AC current. As current flows through the armature windings, the electromagnetic field repels the nearby magnets with the same polarity, and causes the winging to turn to the attracting magnets of opposite polarity. As the armature turns, the commutator reverses the current in the armature coil to repel the nearby magnets, thus causing the motor to continuously turn. This motor can be driven by DC power; hence it is very attractive for low-cost applications. However, some drawbacks of brushed DC motor are the arcing produced by the armature coils on the brush-commutator surface generating heat, wear, and electromagnetic interference (EMI). These characteristics of the brushed motor indicate that it is more suitable in applications where high efficiency is not a major concern. This renders use of this type of motor less attractive in EV applications.[3]

E. Brushless DC motor

The brushless DC (BLDC) motors are the most popular and widely used in control application [28] and are configured into single-phase, 2-phase and 3phase. The simple structure, ruggedness, and low-cost of a BLDC motor make it a viable candidate for various general purpose applications. The BLDC combined with a suitable controlled converter provides several desired characteristics for an efficient drive system. One major advantage of BLDC is enhanced speed versus torque characteristics as compared with other electric motors. Furthermore, the BLDC accomplishes commutation electronically using rotor position feedback to determine when to switch the current. This motor is built with a permanent magnet rotor and wire-wound stator poles. The rotor is formed from permanent magnet and can alter from two-pole to eight-pole pairs with alternate North (N) and South (S) poles. The stator windings work with the permanent magnets on the rotor to generate a uniform flux density in the air gap. This permits the stator coils to be driven by a constant DC voltage (hence the name brushless DC). The rotor position of a BLDC sensed using hall effect sensors is very important, this gives the information about winding that is energized at the moment and the winding that will be energized in sequence [34]. Whenever the rotor magnetic poles pass near the hall sensors, they give a high or low signal, suggesting the N or S pole is passing near the sensors. The exact order of commutation can be estimated, depending upon the combination of these three hall sensor signals. [3]

Furthermore, Sensorless control strategies can be used to eliminate the position sensors, thus reducing the cost and size of motor. In fact, control methods, such as back-EMF and current sensing can provides enough information to estimate with sufficient precision the rotor position and, therefore, to operate the motor with synchronous phase currents. Perhaps, the most popular BEMF methods rely on one technique called the zero crossing point (ZCP), being the only point to provide the rotor position information at either 00 or 1800 electrical. The zero crossing point methods are succeeded by a phase shift of 300 or 900 to match the commutation instances. Any detection error of the ZCP results in a sub-optimal phase current.[3]

A conceptual method which uses extended kalman filter for estimating the exact commutation instance of a winding is suggested. This method shall be further developed, validated and reported.The BLDC motor offers excellent power density as compared to other motors, higher torque, reduced operational and mechanical noise, elimination of electromagnetic interference and offers excellent efficiency. Hence, this motor is the most popular in EV application [3]

IV. Conclusion

Electric Vehicle has different parts some of the important parts are motors and batteries have been discussed here. Battery in Electric Vehicles plays vital role though there are many types are found but to decide a battery is main role. The BLDC motor offers excellent power density as compared to other motors, higher torque, reduced operational and mechanical noise, elimination of electromagnetic interference and offers excellent efficiency. Hence, this motor is the most popular in EV application.

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