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COMPARATIVE STUDY OF DIFFERENT TYPES OF MOTORS USED IN ELECTRIC VEHICLE

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Abstract: Electric vehicles (EVs) powered by induction motors represent a significant shift in sustainability in the automotive industry. Induction motors, known for their efficiency and reliability, play an important role in this transformation. This topic explores the key features and benefits of electric vehicles with induction motors. Equipped with an induction engine, the electric car offers environmental solutions by reducing carbon emissions and reducing dependence on fossil fuels. The simplicity of asynchronous motors helps reduce maintenance costs and increase durability, improving the overall economics of electric vehicles. Eliminating the drive in the asynchronous motor in an electric car simplifies the design of the car, making it easier to use, more powerful and more efficient. Additionally, these engines facilitate regeneration, converting kinetic energy back in to electrical energy and increasing overall energy efficiency.

Keywords**:** Electric vehicle, Induction Motor, Permanent Magnet Synchronous Motor, Rotor Speed, Efficiency.

I. INTRODUCTION

In EV's, electric energy is the main source of power for propulsion of a vehicle. Electric vehicles are one of the critical milestones on our path to sustainability. Induction motors, known for the efficiency and reliability has advantages of simple structures, low prices, easy maintenance, broader constant power operation scope and so on has a broadcast application in electric vehicle fields. The use of electric power for driving has become a reality due to development of better batteries technology. The importance of moving towards environmentally friendly transportation options is now acknowledged by governments, industries and consumers globally, and electric cars have evolved into an essential driver for change in this regard. Although most of the electric vehicle producers employ BLDC motors, their availability is limited, and they are only appropriate for the small size of urban or sophisticated electric vehicles which rarely bear the heavy load and rugged situations. However, induction motors are currently being employed in heavy duty three-and four-wheel vehicles. In order to store the energy in a storage cell, solar rooftops can be suggested for electric vehicles. Solar roofing might also improve the battery life and distance running of an electric vehicle. With an increasing awareness for environmental sustainability and unstoppable search for greener technologies, automobile industry finds itself in the middle of a revolutionary change. Electric Vehicles are one of the critical milestones on our path to sustainability. In the face of challenges presented by climate change, air pollution, and exhaustion of limited natural resources, transportation electrification serves as the torchlight for progress. Electric vehicle adoption is more than just a movement because it is necessitated by circumstances and events happening at a moment in time. The use of electric power for driving have become a reality due to development of better batteries technology, improvement of power infrastructure supply and a change in public opinion concerning fossil fuel combustion engines negative influence on environment. The importance of moving towards environment friendly transportation options is now acknowledged by governments, industries and consumers globally, and electric cars have evolved into an essential driver for change in this regard.

II. ELECTRIC MOTOR USED IN EVS

A variety of motor applications are used in electric vehicles. An electric motor's primary use is for propulsion, but it can also be used for other purposes like window sliding, front and rear wipers, seat adjustment etc. Most of these applications can be powered by electric vehicle ride out with just a DC motor while the primary prime mover is sometimes connected across the front wheel to increase efficiency. Because a prime mover for a commercial application as a significant component is most appropriate, one of the AC motors, Squirrel Cage induction Motor is taken into consideration. and to increase vehicle efficiency thanks to its durability and low maintenance requirements. Although the induction motor is more favorable than all other types of motor used in electric vehicles, excess power received by the induction motor is used to move the vehicle at varying loads. Now that we have three-phase symmetrical windings and a square wave for the air gap, we need to compare the performance evaluation of BLDC and induction Motors for any electric vehicle.

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Armature reactions are observed as negligible but at the inner surface of the stator where they are continuously distributed in a BLDC motor.

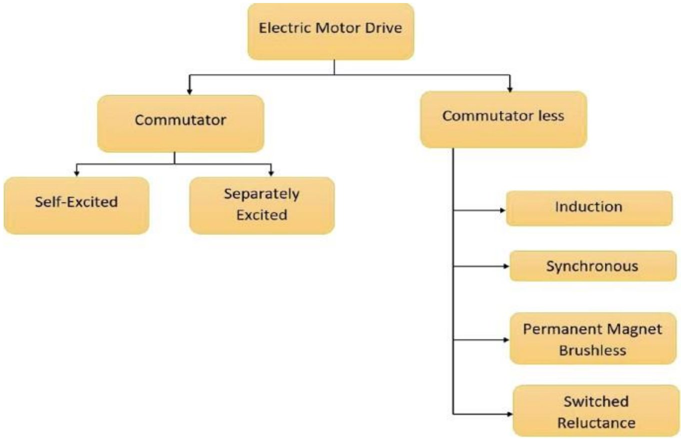

Fig.1 Categories of electric motor

III. EVALUATION OF MOTOR DRIVE FOR AN ELECTRIC MOTOR

A. Induction Motor

AC electric motor an asynchronous motor or induction motor in which the electric current in the rotor needed to produce torque is obtained from the magnetic field of the stator winding by electromagnetic induction. Without electrical connections to the rotor an induction motor can be made. Rotor can be either squirrel-cage type or wound type in an induction motor. Figure 2 shows the equivalent circuit of induction motor. Due to the electromagnetic induction the stator winding produces magnetic field and current is induced in rotor which produces torque that is the working principle of an Induction Motor.

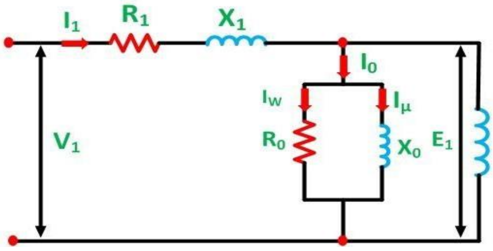

Fig. 2 Equivalent circuit of induction motor

Faraday's law of Electromagnetic Induction works no electrical connection exists between stator and rotor that differ from other motors (DC, Synchronous). Due to AC oscillations, the AC power supplied to the stator create magnetic field, this changing magnetic field produces changing attractive transition that incites a current in rotor windings as per Faraday's law. Table1give the parameters and ratings of induction motor.

Table.1 Parameters and ratings of induction motors

Motor parameters	Ratings
Rotor inertia (j)	0.000145kgm
No. of poles(p)	4
Stator resistance Rs	0.1607
Rotor resistance Rr	0.1690
Rotor self-inductance (Lr)	7.22mH
Stator self-inductance (Ls)	7.2mH
Magnetizing inductance (Lm)	6.38mH
Rated power	200W
Rated speed	3621rpm

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B. Permanent Magnetic Synchronous Motor (PMSM)

The highly conductive materials alike Samarium-Cobalt and Neodymium-Iron-Boron, and high permeability is carried out on the permanent magnets, this is very suitable material why because cost effectiveness and availability. Those magnets can be seen on the rotor core. The PMSM motor is categorized into interior PMSM, and Surface mounted PMSM. The PMSM motor and the synchronous motor working is similar. The three phase arrangements of the motor is energized through the three phase supply, and the magnetic field is set up in the air gap. At a particular speed the rotating magnetic fields lock with that of rotor field in order to induce the torque to rotate the motor. From which we can understand the synchronous motors are not a self- starting, but it needs something. While because there are no windings on the rotor, such a motor is work out by the power supply and variable frequency. Table 2 shows the parameters and ratings of permanent magnet synchronous motor.

Table.2 Parameters and ratings of PMSM

Motor parameters	values
Mutual inductance	0.156
Stator and Rotor inductance (Ls, Lr)	0.171
Stator and Rotor resistance (Rs, Rr)	1.34
Friction coefficient(B)	0.002
Motor inertia(j)	0.05
Rated torque	4Nm
No. of Poles(P)	6
Frequency	50HZ
Type	3phase
Rated current	7.4A
Rated voltage	120V
Rated power	1.5KW

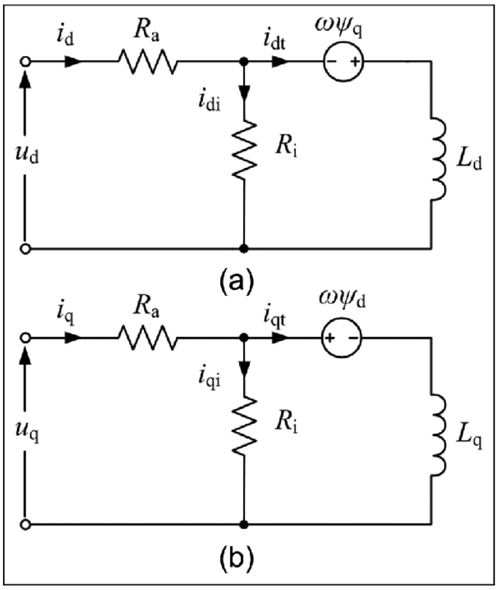

Fig.3 Equivalent circuit of PMSM

C. Brushless DC Motor

An electronically driven motor might be depicted as Brushless DC motor which does not have brushes. These kinds of motors are extremely efficient in creating a lot of torque over a massive speed range. In brushless motors, permanent magnets pivot around a settled armature and conquer the issue of associating current to the armature. Substitution with gadgets has an expansive extent of capacities and adaptability. They are known for smooth task and holding torque when stationary. The BLDC motor uses electrical compensation with the permanent magnet rotor and a stator with a progression

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of coils. This electrical substitution association expels the commutators brushes in a DC motor and hence the most faithful and less uproarious process is accomplished. The BLDC motors can ride at high speeds as a result of the absence of the brushes. The capability of the BLDC motors is typically 85:90 ratio, while as the brushed sort DC motors are 75:80 proportion adequate. The brushless DC motor will deal with the rule that identified with a traditional DC motor. Particularly the Lorentz force law expresses that whatever a current conveying conductor settled in a magnetic field will exposures a power. The magnet will rehearse an equivalent and inverse power, as a recompense of reaction force. The current conveying conductor is static in the condition when the permanent magnet moves its location, during the function of brushless DC motor. At the point when the stator coils are electrically exchanged by a supply source. It transforms into electromagnet and begins producing the uniform field in air gap.

Table.2 Parameters and ratings of BLDC

Motor parameters	values
Rated speed	2500rpm
Rated torque	17Nm
Maximum speed	4000rpm
Rated output power	4.5KW
Operating Voltage	48V
Motor weight	10kg

IV. PARAMETERS

I.*Torque-speed characteristics*

The performance and suitability of an electric motor for a particular application can be decided by its torque-speed characteristics. Torque-speed characteristics are also called as mechanical characteristics. The ideal mechanical characteristics of an electric motor for electric vehicle application are as shown in Figure 4. When electric vehicle is used where frequent staring/stopping is required, motor is operated in constant torque region, while at high speed; it is operated in constant power region. DC series wound motor has high starting torque. Also, speed decreases with increase in torque. DC shunt motors have medium staring torque, but speed decreases slightly with increase in torque. Therefore, DC shunt wound motors are used in constant speed application.

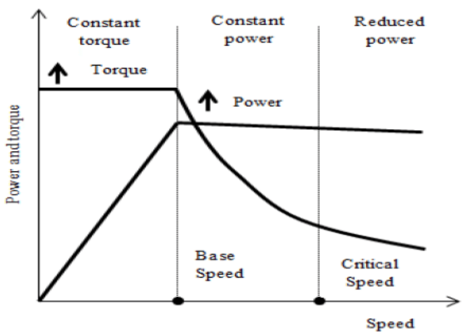

Fig.4 Ideal mechanical characteristics of EV

The torque-speed characteristics of an induction motor depict the relationship between its torque output and rotational speed. Initially, high starting torque is needed, which decreases as speed increases until it reaches the pull up torque, the minimum required for acceleration. Beyond this, torque diminishes until reaching the breakdown torque, the maximum sustainable torque. At full-load, the motor operates at its rated torque. Speed is determined by slip, the difference between synchronous and rotor speed. These characteristics are vital for selecting appropriate motors for specific applications and understanding their performance under varying loads.

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The torque-speed characteristics of a permanent magnet synchronous motor (PMSM) exhibit a linear relationship between torque and speed. At low speeds, torque is high due to the strong magnetic field generated by permanent magnets. As speed increases, torque decreases linearly until reaching a point where torque drops to zero at synchronous speed, where rotor and magnetic field synchronize. Beyond this point, torque is negative, preventing motor operation beyond synchronous speed. PMSM's offer high efficiency and precise control, making them suitable for applications demanding constant speed operation or where variable speed control is required, such as in industrial automaion and electric vehicles.

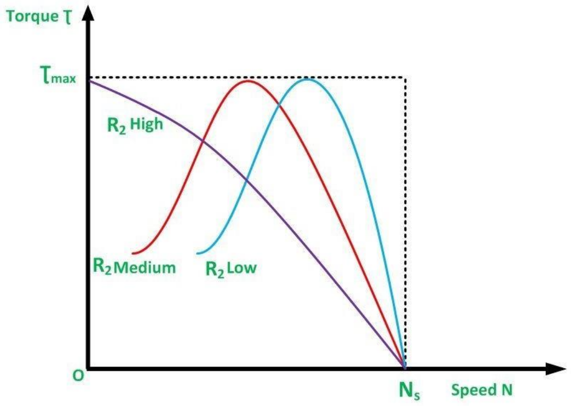

Fig5 Torque-Speed characteristics of induction motor

The torque-speed characteristics of a brushless DC (BLDC) motor demonstrate a linear relationship between torque and speed. Initially, at low speeds, torque is high due to the strong magnetic field generated by permanent magnets. As speed increases, torque decreases linearly until reaching a point where torque diminishes to zero at the motor's maximum speed. BLDC motors offer efficient and precise control over a wide speed range, making them ideal for various applications, including electric vehicles, drones, and industrial machinery. Their brushless design ensures minimal maintenance requirements and improved reliability compared to brushed DC motors, making them a popular choice in modern electromechanical systems.

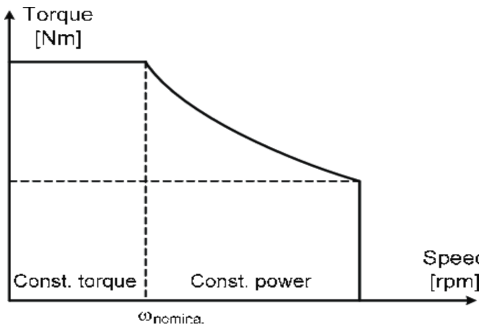

Fig.6 Torque-speed characteristics of permanent magnetic synchronous motor

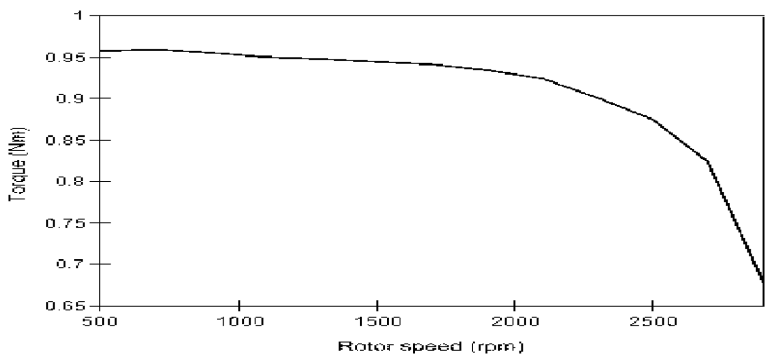

Fig.7 Torque-speed characteristics of BLDC

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II.Efficiency

Motor is an electromechanical device which converts electrical energy into mechanical energy. Whole of input electrical energy is not converted into mechanical energy but is lost due to various factors. Electrical efficiency of an electric motor gives us relation between electrical input and useful mechanical output of motor and is generally given by ratio of shaft power output and motor input power Generally, all electric motors are designed to operate at maximum efficiency at rated output of a motor. When an electric motor is used in electric vehicle, motor will be operated at different loads. Therefore, peak efficiency and efficiency at different loads of a motor must be considered before choosing it for an electric vehicle application.

Table 3 Efficiency comparison of EV motors

Motor Type	Peak efficiency(percent)	Efficiencyat10%load
Induction motor	90	90
Synchronous motor	92	90
Brushless DC motor	95	90

III.*Cost of Controllers*

Motor controllers are an important part of drive system of an electric vehicle. Motor controller in electric vehicles offers improved performance, efficiency and controllability. If an electric vehicle manufacturer wants to build a low-cost electric vehicle, then choosing a low-cost controller would eventually affect his choice for motor. For low voltage electric motor widely used in electric vehicle cost of controllers of different electric motors with same voltage and output power ratings, is as shown below.

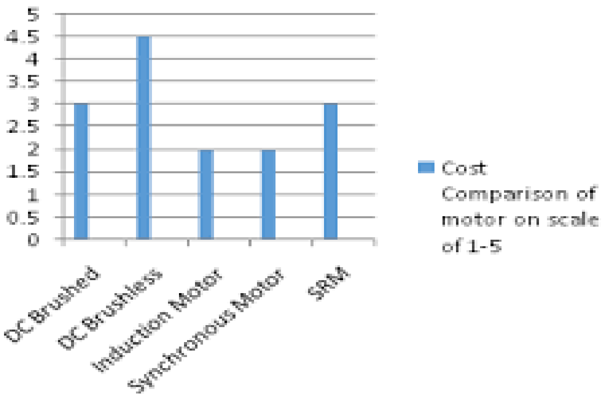

Figure.8 Cost of Controller Comparison for Different Electric Motor

IV.Cost of Motors

One of the important challenges ahead of electric vehicle manufacturers is to provide consumer with an electric vehicle which is as good as gasoline vehicle but within an affordable price. Cost of different electric motors with same voltage and output power ratings are compared as shown below.

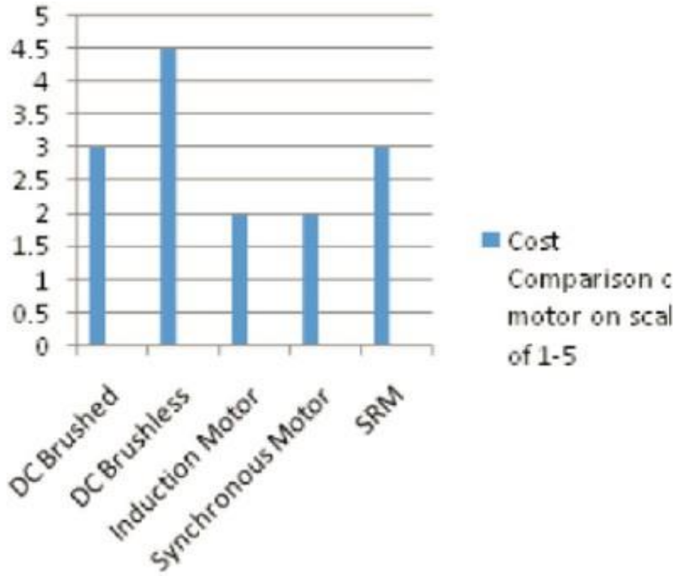

Fig.9 Cost of Motors Comparison for Different Electric Motors

V.CONCLUSIONS

In this paper, we compare three different electric motors for electric vehicle application on different criterions like power-to-weight ratio, torque-speed characteristics, efficiency, cost of controller and cost of motor. Comparative evaluation indicates the following.

- BLDC motor has higher power-to-weight ratio, but its maintenance cost, cost of controller is high.
- Three phase induction motor provides efficiency more than 90% at peak load as well as at 10% load.
- Three phase induction motor and BLDC motor are the two most widely used motors by electric vehicle manufacturers.
- Synchronous motor has higher efficiency at lower speeds and improves battery utilization and driving range. Synchronous motor is preferred where constant torque is required.

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